INDOOR AIR QUALITY ASSESSMENT

John M. Tobin School
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Cambridge, Massachusetts

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Emergency Response/Indoor Air Quality Program
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Background/Introduction

At the request of the Cambridge Health Department, the Massachusetts Department of Public Health (MDPH), Bureau of Environmental Health Assessment (BEHA), provided assistance and consultation regarding indoor air quality concerns at the Tobin School (TS) in Cambridge, Massachusetts.

A series of visits were made to assess the TS during various weather conditions, including rain on November 6, 2002, snow on December 6, 2002 and clear skies on December 2, 2003. On November 6, 2002, Mike Feeney, Director of BEHA's Emergency Response/Indoor Air Quality (ER/IAQ) Program, made an initial visit to conduct an indoor air quality assessment. Mr. Feeney made a subsequent visit on December 6, 2002. Paul Toner, President of the Cambridge Teachers Association (CTA), accompanied Mr. Feeney on November 6th and December 6, 2002. For the December 6, 2002 visit, Mr. Feeney and Mr. Toner were accompanied Cory Holmes an Environmental Analyst in the ER/IAQ Program. On December 2, 2003, Sharon Lee, an Environmental Analyst in the ER/IAQ Program, Mr. Holmes and Mr. Feeney returned to the TS to complete air monitoring with equipment unavailable to staff during the previous two visits. The TS was surveyed under varying weather conditions to ascertain the performance of the building envelope.

The TS is a three-story cement slab/concrete building constructed in 1970. The third floor consists primarily of science rooms, computer labs, a library, an auditorium and general classrooms, while the second floor is composed of offices, a gymnasium, and additional classrooms. The first (ground) floor contains an art room, cafeteria/kitchen, after school rooms, mechanical storage, custodial areas and access to two large crawlspaces (the east and west crawlspaces). A third crawlspace exists beneath the wing containing the gymnasium (the north crawlspace). Openable replacement windows were reportedly installed throughout the building in 1989.

Summary of Historical Environmental Testing

The Cambridge School Department (CSD) provided BEHA staff with copies of reports, letters, and memorandum concerning a number of indoor air quality investigations conducted at the TS dating from 1985 to 2000. These reports suggest that the TS has a long history of concerns relating to landfill materials underlying the school and other IAQ issues. The CSD has made numerous attempts to address air quality issues within this building. Activities taken prior to MDPH's involvement can be divided into two general categories: actions to address concerns related to the landfill pollutants and actions addressing general IAQ.

Actions Addressing Landfill Pollutant Concerns

At least six consultants were hired to determine the extent of contamination in the ground beneath the TS, as well as to address indoor air quality complaints related to the crawlspaces. Initial concerns promoted an assessment of the TS site for hazardous materials. As reported by Camp, Dresser and McKee (CDM), NUS Corporation conducted a health risk assessment in September 1985 (CDM, 1997) (Note: BEHA staff were not provided a copy of the NUS report). The investigation reportedly focused on health risks associated with the alleged on-site disposal of hazardous materials from local chemical and industrial manufacturers (CDM, 1997). The *Preliminary Assessment of the TS* was prepared by NUS and reviewed by the U.S. Environmental Protection Agency (EPA) Region I Superfund

Branch. According to CDM, in June 1995, EPA determined that "no further remedial action" for hazardous materials alleged to exist on the TS site was deemed necessary (CDM, 1997).

In response to odor complaints and crawlspace concerns, Haley & Aldrich, Inc (H&A) was hired to monitor crawlspace levels of volatile organic compounds[1] (VOCs) and methane gas[2]. Air monitoring was conducted in all three crawlspaces. At the time of the 1986 investigation, the crawlspaces were reportedly used to store a variety of materials, such as furniture, machinery, solvents, and paints. The north crawlspace was also reportedly used as storage area for VOC containing products (e.g. solvents and paints). To eliminate methane gas accumulation in crawlspaces and to prevent a fire hazard, H&A recommended sealing separated and/or settled floor slab areas with a sealing compound (H&A, 1986).

To further address air quality and crawlspace concerns, Environmental Health & Engineering Inc. (EH&E) conducted an assessment at the TS from October 1990 through January 1991. This assessment addressed crawlspace concerns, as well as indoor air concerns, discussed later in this report. The EH&E assessment report released in April 1991 detailed monitoring results for TVOCs in the crawlspace. To minimize the intrusion of soil gas into the crawlspace, EH&E recommended the repair and sealing of breaks in the foundation (EH&E, 1991).

Due to continued air quality and crawlspace concerns, another consultant, Simpson Gumpertz & Heger, Inc. (SGH), was hired in August 1991. To address VOC concerns, SGH recommended removal of materials stored in the crawlspaces. SGH also provided design

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[1] VOCs and methane gas can be produced from landfills through the decomposition of materials within a landfill. Another possible source of VOCs in landfills can be from disposal of chemicals.
[2] Methane gas is a highly flammable material that has limited physiological effects. Concentrations of methane in a confined space can be a serious fire hazard.

recommendations and oversight to remedial projects. As recommended by SGH, various consulting firms under contract provided the following services:

1. Installed a temporary membrane barrier and sealant in crawlspaces;
2. Installed a sub-slab ventilation system in crawlspaces and the floor of Room 129;
3. Monitored for indoor methane and VOC levels;
4. Investigated soil gases;
5. Installed and tested of HVAC system upgrade;
6. Designed and installed a subsurface gas extraction system; and
7. Designed and installed a permanent crawlspace barrier (SGH, 1991; McGrath, 1991a; McGrath, 1991b).

The impermeable membrane barrier and sub-slab ventilation system installations were completed in September 1991 (Pictures 1 through 4).

One month following these installations, GEI Consultants, Inc. (GEI) conducted soil gas testing[3]. Testing for soil gas was conducted on October 23, 1991. On November 21, 1991, GEI gave verbal notification to the CSD that preliminary analysis of data indicated elevated soil gas levels of methane and VOCs (McGrath, 1991c). Under the direction of the Cambridge School Department, pursuant to Massachusetts General Law Chapter 21E (MGL c.21E) and the Massachusetts Contingency Plan (MCP) (310 CMR 40.000), GEI contacted the Massachusetts Department of Environmental Protection (DEP) to notify the agency of the "release or potential threat of release of hazardous materials" (McGrath, 1991c). In a letter issued December 17, 1991, the DEP concluded an "imminent hazard" *did not exist* in the

[3] Soil gas testing refers to the sampling of gases in subsurface areas below the temporary barrier system in the crawlspace locations.

school, as the crawlspace ventilation system was operating as designed (DEP, 1991; emphasis added).

In a letter report issued March 5, 1992, GEI concluded: "the presence of VOCs and significant methane concentrations indicates that a release of hazardous materials has occurred on or adjacent to the TS…[however] the source of the VOCs and methane is unknown." GEI indicated that the east crawlspace was of greatest concern as significant methane and VOC soil gas concentrations were detected. Because soil gas testing was conducted only after the sub-grade venting system was installed, the history, extent and distribution of the soil gas contamination could not be determined. GEI recommended continued operation of the sub-slab ventilation system to prevent methane and VOC entrainment to occupant areas (GEI, 1992).

Another consultant, OccuHealth, Inc. (OHI), conducted air testing for methane and VOCs concurrent to GEI soil gas sampling in 1991. Air testing was conducted on October 23, 1991 and samples were collected from each of the sub-slab ventilation systems exhaust stacks, as well as in classrooms, crawlspaces, and outside. OHI found that VOC levels found in all areas of the TS were within expected ranges of indoor concentrations reported by the US EPA (OHI, 1991). Trace levels of methane were also detected. According to OHI, prior to the installation of the barrier and sub-slab ventilation system, methane levels were "unacceptably high" (e.g. 1000 ppm in 1986 and 160 ppm in spring 1991) (OHI, 1991). To maintain methane levels at lower readings, OHI recommended the following:

1. Install a supervised methane gas monitoring system in the three crawlspaces and the main hallway above the cafeteria; and
2. Conduct bimonthly methane monitoring for the following:

a. Air within the TS at selected sites, including the three crawlspaces and classrooms located on each floor;
b. Stack gases exiting the six sub-slab suction systems; and
c. Ambient air around the TS (OHI, 1991).

In the months following (i.e. from September 24, 1992 to October 22, 1992), OHI conducted methane monitoring. The initial assessment found no methane at the test ports. Tests also indicated a good static pressure field under the concrete slab in nearly all of the ports. The major exception was Room 129, where no negative pressure was detected. This was attributed to a potential blockage or improper installation. An investigation was launched to determine the cause for lack of pressure in this area. Subsequent monitoring was conducted on a monthly basis. Follow-up reports indicate that methane levels were being effectively controlled by the crawlspace ventilation system. OHI recommended continued operation of the crawlspace ventilation system (OHI, 1992a).

CDM conducted a Phase I Limited Subsurface Investigation in 1997 "to determine whether a release of contaminants has occurred associated with the fill material beneath the Tobin Elementary School property [and] evaluate the hazards associated with the fill material" (CDM, 1997). This investigation was conducted at the behest of the MA Department of Environmental Protection (DEP) after a request from the CSD, pursuant to DEP regulation (310 CMR 40.0000) concerning hazardous waste. CDM completed the following activities as part of this investigation:

1. Conducted a ground conductivity survey to map the location of the fill materials;
2. Sampled and analyzed groundwater from existing monitoring wells in the area; and

3. Collected and analyzed soil gas samples from beneath the school and from the roof vent stacks (CDM, 1997).

CDM reported finding "no evidence of total petroleum hydrocarbons (TPH), VOCs, semi-VOCs or trace metal contamination of groundwater in direct contact with landfill materials". CDM made the following conclusions:

1. No fill material was found on ground surface areas, therefore the risk of exposure through direct contact was unlikely;
2. The potential for groundwater exposure to hazardous materials inside the building was unlikely;
3. The lack of fill decomposition halted methane generation; and
4. Any remaining VOCs and methane were actively being eliminated by the specially retrofitted crawlspace venting systems; therefore, any potential for inhalation exposure was also unlikely.

As a result of the CDM assessment, the DEP classified the TS as a Tier II site, a site with lower potential risk to human health and/or the environment.

Actions Addressing Indoor Air Quality

As previously mentioned, an indoor air quality assessment was conducted by EH&E from October to December 1990. In addition to crawlspace TVOC levels, the report detailed monitoring results for selected pollutants (e.g. VOCs, respirable suspended particulate matter, pesticides, microbes, dust mites and carbon dioxide) and provided an assessment of the ventilation system. The 1991 EH&E report made a number of recommendations to improve indoor quality in the TS. These recommendations included:

1. Remove all carpeting that has been damaged by water and disinfect underlying area with a bleach solution;
2. Implement and adhere to a scrupulous cleaning regimen when using humidifiers;
3. Examine and maintain unit ventilators (univents) for proper functioning, replacing malfunctioning parts as needed;
4. Familiarize occupants with the functions of the unit ventilator and encourage occupants to keep univents turned on;
5. Lower temperature settings and adjust diffusers to increase air movement and enhance comfort levels; and
6. Reduce noise generated by univents (EH&E, 1991).

Long-term recommendations included the modification or replacement of existing ventilation systems in response to increases to class size or changes to room usage (EH&E, 1991).

As indicated by the EH&E report, the condition and proper functioning of univent systems were also of concern. To address these concerns, OHI also conducted an assessment of the ventilation system at TS in 1991. The preliminary report, issued January 1992, recommended replacement of the existing univent system. OHI also recommended energy management measures as a means of conserving energy and improving control to the HVAC system. Recommended conservation measures include the conversion of the hot water heater from electric to natural gas and upgrading of the large HVAC units for the auditorium, gymnasium and general areas with new gas fired rooftop units (OHI, 1992b).

As recommended by EH&E and OHI, the classroom ventilation system was replaced. Univents were replaced in July 2002. The remainder of the new HVAC system and related components were installed by September 2002. A number of damaged and malfunctioning louvers were subsequently replaced.

OHI conducted a number of indoor air quality assessments subsequent to their initial visit in 1991. Testing was conducted by OHI in March 1999, February 2000, and November 2000. Assessments made by OHI are divided into two general categories: mold sampling and TVOC sampling.

Mold Sampling

On March 3, 1999, OHI conducted indoor air monitoring after water was found entering offices through a roof leak. OHI recommended affected areas be “fogged” with an anti-microbial sanitizer containing an ammonium compound (OHI, 1999) to remove possible mold contamination. OHI returned in October 2000 to conduct further microbial monitoring. OHI concluded that “indoor concentrations of viable airborne fungi were well within accepted levels” (OHI, 2000a).

Continued complaints of indoor air quality prompted additional test requests. OHI was requested to assess indoor air quality in February 2000 and again in November 2000. Air samples were collected for airborne viable fungi levels, as well as for the characterization of airborne dust. The February 2000 report concluded that airborne fungi concentrations were “well within accepted levels”, and all fungal types identified were commonly found in building environments. Additionally, dust types found in the building were common forms typically found in schools. Sources of dust included building occupants and building materials, as well as outdoors. (OHI, 2000b)

Similar results were found during the November 2000 reassessment. Indoor fungi levels were within accepted levels. As with previous results, fungi and dust identified in the building are common to building environments. OHI concluded that the intense activity level and increased flow of outdoor air contributed to elevated particle measurements. (OHI, 2000c)

TVOC Sampling

OHI also conducted TVOC sampling in February 2000 and November 2000. Air samples were collected for the determination of TVOC concentrations. The February 2000 assessment concluded that a majority of areas sampled had TVOC levels that were "very close to normal." Slightly elevated TVOC levels measured in some areas could be attributed to recent painting activities at the school (OHI, 2000b). Similar results were found during the November 2000 reassessment. According to the November 2000 OHI report, concerns were raised regarding the level and type of TVOCs found in the gymnasium crawlspace. These TVOC levels, as well as other measurements made through out the building were "statistically equivalent" to outdoor TVOC measurements. OHI concluded that the test results confirm that the sub-slab ventilation system is operating as designed (OHI, 2000c)

As mentioned previously, the MDPH was asked to evaluate information collected to date, relative to IAQ at the TS and to conduct an indoor air quality assessment. The remainder of this report focuses largely on the results of the MDPH assessment.

Methods

BEHA staff conducted air tests for carbon dioxide, carbon monoxide, temperature and relative humidity with the TSI, Q-TRAK™ IAQ Monitor, Model 8551. Air tests for airborne particle matter with a diameter less than 2.5 micrometers were taken with the TSI, DUSTTRAK™ Aerosol Monitor Model 8520. Screening for total volatile organic compounds (TVOCs) was conducted using a Thermo Environmental Instruments Inc., Model 580 Series Photo Ionization Detector (PID).

Results

The TS has a student population of approximately 400 in grades K-8, s well as a staff of approximately 60. Tests were taken during normal operations at the school and results appear in Tables 1 - 3.

Discussion

Ventilation

It can be seen from the tables that carbon dioxide levels were elevated above 800 parts per million of air (ppm) in two of twenty-seven areas surveyed on November 6, 2002 and in four of thirty-six areas surveyed on December 6, 2002. Carbon dioxide levels were also elevated above 800 parts per million of air (ppm) in fourteen of sixty-one areas surveyed on December 2, 2003. These measurements indicate adequate ventilation in most areas of the school; however, some classrooms had open windows or were sparsely populated during the assessment. These factors can greatly contribute to reduced carbon dioxide levels.

Fresh air in classrooms is supplied by a unit ventilator (univent) system. Univents draw air from outdoors through a fresh air intake located on the exterior walls of the building and return air through an air intake located at the base of each unit (Figure 1). Fresh and return air are mixed and filtered, then heated and provided to classrooms through an air diffuser located in the top of the unit. Obstructions to airflow, such as papers and books stored on top of univents and bookcases and carts and desks placed in front of univent returns, were seen in a number of classrooms (Picture 5). Univents were found deactivated in some classrooms. In order for univents to provide fresh air as designed, intakes must remain free of obstructions. More importantly, these units must remain activated and allowed to operate while these rooms are occupied.

Classroom exhaust ventilation is powered by rooftop motor. Air is drawn into the coat closet from the classroom via under and over-cut closet doors (Picture 6). Exhaust ventilation grilles are located in the ceiling of coat closets. The location of these closet vents allows them to be easily blocked by stored materials (Picture 7). As with the univents, in order to function properly, exhaust vents must remain free of obstructions.

Fresh air in the gymnasiums, locker rooms and the auditorium is provided by air handling units (AHUs). Outside air is drawn through intake louvers. Ductwork connecting AHUs to ceiling or wall diffusers facilitate distribution of fresh air to occupied areas. Return air is drawn into exhaust vents and returned to the AHUs via ductwork. These systems were operating during the visits.

In order to have proper ventilation with a mechanical supply and exhaust system, these systems must be balanced to provide an adequate amount of fresh air to the interior of a room while removing stale air from the room. According to school department officials, the date of the last balancing of these systems was in 1991-1992. It is recommended that existing ventilation systems be re-balanced every five years to ensure adequate air systems function (SMACNA, 1994).

The Massachusetts Building Code requires that each room have a minimum ventilation rate of 15 cubic feet per minute (cfm) per occupant of fresh outside air or have openable windows (SBBRS, 1997; BOCA, 1993). The ventilation must be on at all times that the room is occupied. Providing adequate fresh air ventilation with open windows and maintaining the temperature in the comfort range during the cold weather season is impractical. Mechanical ventilation is usually required to provide adequate fresh air ventilation.

Carbon dioxide is not a problem in and of itself. It is used as an indicator of the adequacy of the fresh air ventilation. Rising carbon dioxide levels indicate that the ventilating system is malfunctioning or the design occupancy of the room is being exceeded. When this happens a buildup of common indoor air pollutants can occur, leading to discomfort or health complaints. The Occupational Safety and Health Administration (OSHA) standard for carbon dioxide is 5,000 ppm. Workers may be exposed to this level for 40 hours/week based on a time-weighted average (OSHA, 1997).

The MDPH uses a guideline of 800 ppm for publicly occupied buildings. A guideline of 600 ppm or less is preferred in schools due to the fact that the majority of occupants are young and considered to be a more sensitive population in the evaluation of environmental health status. Inadequate ventilation and/or elevated temperatures are major causes of complaints such as respiratory, eye, nose and throat irritation, lethargy and headaches. For more information concerning carbon dioxide, please see Appendix A.

Temperature readings ranged from 68° F to 74 ° F on November 6, 2002 and from 68° F to 78 ° F on December 6, 2002. Temperature measurements on December 2, 2003 ranged from 67° F to 75 ° F. As evidenced in the Tables, temperatures for these assessment dates were below the BEHA recommended comfort guidelines in a number of areas. The BEHA recommends that indoor air temperatures be maintained in a range of 70 ^{o} F to 78 ^{o} F in order to provide for the comfort of building occupants. A number of temperature control/comfort complaints were expressed by occupants, throughout the building. In many cases concerning indoor air quality, fluctuations of temperature in occupied spaces are typically experienced, even in a building with an adequate fresh air supply. Moreover, it is difficult to control temperature and maintain comfort without operating the ventilation equipment as designed (e.g., univents deactivated, univents and exhaust vents obstructed). Furthermore, room configuration and design also affect temperature controls. For example, a photocopier in the main office is located directly below the thermostat that controls the temperature for the area. Heated air rising from the photocopier would activate the thermostat, and in turn activate the HVAC system to provide cold air to this area during summer months. In winter, the HVAC system would be deactivated by heated air from the photocopier interacting with the sensors in the thermostat, resulting in cooler room temperatures.

The relative humidity ranged from 38 to 51 percent on November 6, 2002, which was close to the BEHA recommended comfort range. For December 6, 2002, relative humidity measurements ranged from 18 to 31 percent, and on December 2, 2003 from 14 to 25 percent. Relative humidity measurements for both December 6, 2002 and December 2, 2003 were below the BEHA recommended comfort range in all areas surveyed. The BEHA recommends a comfort range of 40 to 60 percent for indoor relative humidity. The sensation of dryness and irritation is common in a low relative humidity environment. Humidity is more difficult to control during the winter heating season. Low relative humidity is a very common problem during the heating season in the northeast part of the United States.

Microbial/Moisture Concerns

The building has a history of water penetration problems. A number of areas had water-damage and stained building materials (e.g., walls or ceilings), which can indicate leaks from the roof or plumbing system (Picture 8). Active roof leaks were reported in hallway areas outside of classrooms 306 and 308. Buckets were stationed throughout the hallway to catch dripping rainwater (Picture 9). Water-damaged porous building materials can provide a source for mold and should be replaced after a water leak is discovered.

Efflorescence (e.g., mineral deposits) was observed in a number of classrooms (Pictures 10 through 13). Efflorescence is a characteristic sign of water damage that appears on building materials such as brick or plaster, but it is not mold growth. As moisture penetrates and works its way through mortar and brick, water-soluble compounds dissolve, creating a solution. As the solution moves to the surface of the brick or mortar, water evaporates, leaving behind white, powdery mineral deposits. This condition indicates that water from the exterior has penetrated into the building.

A number of structural conditions have created pathways that allow for moisture to penetrate the building interior. These include the following:

1. Univent fresh air intake (UFAI) orientation: In most buildings assessed by BEHA staff, the exterior univent fresh air intake (UFAI) grilles are installed with the louvers parallel to the ground (Picture 14). These louvers are usually beveled, in a manner similar to a peaked roof on a house, so as to direct rainwater away from the univent opening. The UFAI louvers at the TS were installed perpendicular to the ground (Picture 15). Rather than directing water to roll off the louver and away from the

univent, this louver configuration allows for driving rain and other forms of precipitation to penetrate into the fresh air intake and accumulate on the floor of the fresh air intake opening. During the December 6, 2002 visit, BEHA staff found several feet of snow accumulating in the fresh air intake of the air handling unit (AHU) in the gymnasium (Pictures 16). Accumulation of rainwater appears to have produced cracking and efflorescence on the exterior cement wall beneath a number of classroom univents (Pictures 17 and 18). UFAIs are also prone to the accumulation of outdoor debris, dirt and other materials that can serve as mold growth media. With repeated water penetration these materials can become chronically moistened, which can result in mold growth.

2. UFAI location and water drainage: The ground floor of the TS is located below ground level. A cafeteria and a number of classrooms are located on the ground floor. UFAIs were installed near ground level in these areas (Picture 19). Of particular note are the cafeteria UFAIs, located at the bottom of a slope (Picture 20). According to building personnel, the cafeteria has flooded during downpours as a result of water entry through the UFAIs. Flooding is the result of improper drainage in areas in front of UFAIs. Improper drainage was also witnessed in front of classroom areas. Crushed stone is used to fill areas adjacent to classrooms, which are located at the front of the building. Storm drains are also installed in these areas. Over time the stones around the drain have settled. The drains are now the highest point in the aforementioned areas, thus impeding proper drainage. Improper drainage causes pooling of water, as noted in an area outside a sub-level classroom.

3. Roof configuration: The TS consists of a multiple level roof structure, upper roofs and lower roofs. Upper roofs form the roof system for the majority of the building, while lower roofs form the ceiling to gymnasium areas, as well as portions of the library wing, on the second level of the building. The lower roofs are joined to the exterior wall of the building (Picture 21). Lower roofs are designed to direct rainwater to drains that are installed in the roof/exterior wall junction (Picture 22). However, the drains are prone to blockage from accumulated materials. Drain blockage results in water accumulation on the rooftop and ultimately water penetration, as evidenced by efflorescence formation on walls in classrooms adjacent to lower roofs (Picture 23). Drain blockage also results in water cascading over the exterior walls of the second level, causing efflorescence to form on interior walls. In addition, portions of the upper roofs are designed to empty water onto lower roofs (Picture 21). Over time, this design has exposed some areas of the exterior wall, which has created pathways for water penetration into the building.

4. Pilaster usage: Pilasters are used extensively throughout the exterior walls (Picture 24). Although typically used for ornamental purposes, pilasters offer some vertical support. These cement structures have a flat surface on the top. A seam is formed where the flat surface of the pilaster and the exterior wall meets. This joint requires sealing to prevent water penetration into the exterior wall. It is a common practice to install flashing in the joints where dissimilar building materials are used in the building envelope. The flashing functions as a transitional surface for rainwater to drain from one surface to another (e.g., in a manner similar to layering shingles on a roof). At the TS, flashing was not installed in the seams formed between the pilasters

and the exterior brick. Instead, these seams are sealed with a caulking compound (Picture 25). Over time, caulking has been weathered. Degraded seals or open seams can allow for water penetration.

5. Exterior wall and support beam: Support beams and floor decking are constructed of concrete beams. In contrast, exterior walls are composed of conglomerate stone blocks, a material that is more porous than concrete. Stone wall slabs are cemented between the concrete support columns. A seam is formed between the different materials. It is likely that the seams between the stone block and cement beams serve as a pathway for rainwater to penetrate the building. Efflorescence was noted on brick walls in classrooms, particularly in areas where the exterior stone wall is in contact with cement support beams.
6. Window frame damage: Gaskets around openable windows were worn or missing (Picture 26). Caulking around windowpanes and frames was also worn, damaged or missing (Picture 27). During the November 6, 2002 visit, BEHA staff noted that cat litter was used to absorb rainwater chronically penetrating through the window frame in one classroom (Picture 28). Seams created by damaged or missing window frame materials are sources for water penetration.

Other potential sources for microbial growth exist. Several classrooms contained plants that are located over univent fresh air diffusers. Plant soil, standing water and drip pans can be a potential source of mold growth. Drip pans should be inspected periodically for mold growth and over watering should be avoided. Plants should also be located away from the air stream of univents to prevent aerosolization of dirt, pollen or mold.

Several classrooms have sinks that had an open seam between the countertop and backsplash (Picture 29). Improper drainage or sink overflow could lead to water penetration of countertop wood, the cabinet interior and behind cabinets. Like other porous materials, repeated wetting of these materials can be conducive to mold growth.

Crawlspace Examination

BEHA staff examined each of the three crawlspaces. The plastic vapor barrier in each crawlspace was intact. Each crawlspace was free of moisture and musty odors during the assessment, indicating adequate draw of air from the crawlspace/subsurface vent system. A faint sewer odor was noted in the west crawlspace; however, no similar sulfurous odor was detected in classrooms and stairwells sharing walls or floors with the west crawlspace. These conditions indicate that the retrofitted exhaust system to intercept landfill-generated gas is operational and prevents migration of odors into occupied areas of the TS.

Other Concerns

Indoor air quality can be negatively influenced by the presence of respiratory irritants, such as products of combustion. The process of combustion produces a number of pollutants; however, the pollutant produced is dependent on the material combusted. Common combustion emissions include carbon monoxide, carbon dioxide, water vapor and smoke (fine airborne particle material). Of these materials, exposure to carbon monoxide and particulate matter with a diameter of 2.5 micrometers (μm) or less (PM2.5) can produce immediate, acute health effects upon exposure. To determine whether combustion products were present in the school environment, BEHA staff obtained measurements for carbon monoxide and PM2.5.

Several air quality standards have been established to address airborne pollutants and prevent symptoms from exposure to these substances. The MDPH established a corrective action level concerning carbon monoxide in ice skating rinks that use fossil-fueled ice resurfacing equipment. If an operator of an indoor ice rink measures a carbon monoxide level over 30 ppm, taken 20 minutes after resurfacing within a rink, that operator must take actions of reduce carbon monoxide levels (MDPH, 1997).

ASHRAE has adopted the National Ambient-Air Quality Standards (NAAQS) as one set of criteria for assessing indoor air quality and monitoring of fresh air introduced by HVAC systems (ASHRAE, 1989). The NAAQS are standards established by the US EPA to protect the public health from 6 criteria pollutants, including carbon monoxide and particulate matter. As recommended by ASHRAE, pollutant levels of fresh air introduced to a building should not exceed the NAAQS (ASHRAE, 1989). The NAAQS were adopted by reference in the Building Officials & Code Administrators (BOCA) National Mechanical Code of 1993 (BOCA, 1993), which is now an HVAC standard included in the Massachusetts State Building Code (SBBRS, 1997).

Carbon monoxide is a by-product of incomplete combustion of organic matter (e.g., gasoline, wood and tobacco). Exposure to carbon monoxide can produce immediate and acute health affects. According to the NAAQS established by the USEPA, carbon monoxide levels in outdoor air should not exceed 9 ppm in an eight-hour average. Outdoor carbon monoxide concentrations were not detectable (Table 3). Carbon monoxide levels measured in the school reflect levels measured outdoors. *Carbon monoxide should not be present in a typical, indoor environment.* If it *is* present, indoor carbon monoxide levels should be less than or equal to outdoor levels.

As previously mentioned, the US EPA also established NAAQS for exposure to particulate matter. The NAAQS originally established exposure limits to particulate matter with a diameter of 10 μm or less (PM10). According to the NAAQS, PM10 levels should not exceed 150 microgram per cubic meter (μg/m^3) in a 24-hour average. These standards were adopted by both ASHRAE and BOCA. Since the issuance of the ASHRAE standard and BOCA Code, US EPA proposed a more protective standard for fine airborne particles. This more stringent, PM2.5 standards requires outdoor air particle levels be maintained below 65 μg/m^3 over a 24-hour average. Although both the ASHRAE standard and BOCA Code adopted the PM10 standard for evaluating air quality, BEHA uses the more protective proposed PM2.5 standard for evaluating airborne particulate matter concentrations in the indoor environment. Outdoor PM2.5 concentrations were measured at 10 μg/m^3 (Table 3). In most cases, PM2.5 levels measured in the school reflect outdoor levels and did not exceed the NAAQS. In some locations, PM2.5 readings were slightly elevated above outdoor levels, but were below the NAAQS PM2.5 standard. Sources of particle measurements in this area of the building are most likely by-products of cooking in the kitchen. The areas with slightly elevated PM2.5 levels were all immediately adjacent to the multi-level cafeteria (e.g. Nurse's Office) or the art room. The art room had plants placed over the univent, which is the likely source of airborne particulate.

Indoor air quality can also be negatively influenced by the presence of materials containing volatile organic compounds (VOCs). VOCs are carbon-containing substances that have the ability to evaporate at room temperature. Frequently, exposure to low levels of total VOCs (TVOCs) may produce eye, nose, throat and/or respiratory irritation in some sensitive individuals. For example, chemicals evaporating from a paint can stored at room temperature would most likely contain VOCs. In an effort to determine whether VOCs were present in the building, air monitoring for TVOCs was conducted. An outdoor air sample was taken for comparison. Outdoor TVOC concentrations were not detectable (Table 3). Indoor TVOC concentrations were also not detectable.

While TVOC levels were not detectable in the indoor air, materials containing VOCs were present in the school. Several classrooms contained dry erase boards and dry erase markers. Materials such as dry erase markers and dry erase board cleaners may contain VOCs (e.g., methyl isobutyl ketone, n-butyl acetate and butyl-cellusolve) (Sanford, 1999), which can be irritating to the eyes, nose and throat.

Also noted on a tabletop were several cans of wood sealant and paint, which were not properly sealed (Picture 31). These products contain VOCs, which evaporate readily and can be irritating to eyes, nose and throat. Additionally, these products are flammable and should be stored in a cabinet that meets the criteria set forth by the National Fire Protection Association (NFPA) (NFPA, 1996).

In an effort to reduce noise from sliding chairs, tennis balls were sliced open and placed on chair legs. Tennis balls are made of a number of materials that are a source of respiratory irritants. Constant wearing of tennis balls can produce fibers and lead to off-gassing of VOCs. Tennis balls are made with a natural rubber latex bladder, which becomes abraded when used as a chair leg pad. Use of tennis balls in this manner may introduce latex dust into the school environment. A box of latex gloves were also found on top of a univent (Table 3). Some individuals are highly allergic to latex (e.g., spina bifida patients) (SBAA, 2001). It is recommended that the use of materials containing latex be limited in buildings to reduce the likelihood of symptoms in sensitive individuals (NIOSH, 1997). A question and answer sheet concerning latex allergy is attached as Appendix B (NIOSH, 1998).

The faculty workrooms have photocopiers and lamination machines. Lamination machines can produce irritating odors during use. VOCs and ozone can be produced by photocopiers, particularly if the equipment is older and in frequent use. Ozone is a respiratory irritant (Schmidt Etkin, 1992). To help reduce excess heat and odors in these areas, school personnel should ensure that local exhaust ventilation is activated while equipment is in use. The second floor faculty workroom is not equipped with local exhaust ventilation.

Several other conditions that can potentially affect indoor air quality were identified. Spray cleaning products were found on countertops and in unlocked storage cabinets beneath sinks in classrooms (Picture 30). Cleaning products contain chemicals that can be irritating to the eyes, nose and throat. Cleaning products should be stored properly and kept out of reach of students.

Also of note was the amount of materials stored inside classrooms. In classrooms throughout the school, items were observed to be on windowsills, tabletops, counters, bookcases and desks (Picture 32). The large number of items stored in classrooms provides a source for dust to accumulate. These items (e.g., papers, folders, boxes) make it difficult for custodial staff to clean. Dust can be irritating to eyes, nose and respiratory tract. Items should be relocated and/or be cleaned periodically to avoid excessive dust build up.

A few classrooms contained assorted caged animals. Porous materials (i.e., wood shavings) can absorb animal wastes and be a reservoir for mold and bacterial growth. Animal dander, fur and wastes can also be sources of respiratory irritants. Animals and animal cages should be cleaned regularly to avoid the aerosolization of allergenic materials and/or odors (NIOSH, 1998).

Some classrooms contained upholstered furniture. Upholstered furniture is covered with fabric that comes in contact with human skin. This type of contact can leave oils, perspiration, hair and skin cells. Dust mites feed upon human skin cells and excrete waste products that contain allergens. In addition, if relative humidity levels increase above 60 percent, dust mites tend to proliferate (US EPA, 1992). In order to remove dust mites and other pollutants, frequent vacuuming of upholstered furniture is recommended (Berry, 1994). It is also recommended that upholstered furniture (if present in schools), be professionally cleaned on an annual basis or every six months if dusty conditions exist outdoors (IICR, 2000). This is due to the relationship of elevated outdoor levels of airborne particulates resulting in increased levels of indoor particulates from sources such as open windows, doors and filter bypass.

Of note was the presence of flying insects (fruit flies) specifically located near the sink area of classroom 282. Under current Massachusetts law (effective November 1, 2001) the principles of integrated pest management (IPM) must be used to remove pests in state buildings (Mass Act, 2000). Pesticide use indoors can introduce chemicals into the indoor environment that can be sources of eye, nose and throat irritation. The reduction/elimination of pathways/food sources that are attracting these insects should be the first step taken to prevent or eliminate this infestation.

Conclusions/Recommendations

Although the installation of a retrofitted crawlspace exhaust vent system is preventing migration of landfill pollutants into the occupied areas of the TS, other conditions noted at the TS raise a number of indoor air quality issues. For instance, a potential source of water penetration may be water drainage capabilities in and around various components of the building structure and equipment. General building conditions, maintenance, design and the operation of HVAC equipment, if considered individually, present conditions that could degrade indoor air quality. When combined, these conditions can serve to further negatively affect indoor air quality. Some of these conditions can be remedied by actions of building occupants. Other remediation efforts will require alteration to the building structure and equipment. For these reasons, a two-phase approach is required. Recommendations consist of **short-term** measures to improve air quality and **long-term** measures requiring planning and resources to adequately address the overall indoor air quality concerns.

The following **short-term** measures should be considered for implementation:

1. Examine each univent for function. Survey classrooms for univent function to ascertain if an adequate air supply exists for each room. Consider consulting a heating, ventilation and air conditioning (HVAC) engineer concerning the calibration of univent fresh air control dampers throughout the school.
2. Maximize air exchange. The BEHA recommends that all ventilation systems that are operable throughout the building (e.g., gym, auditorium, classrooms) operate continuously during periods of school occupancy independent of thermostat control. To increase airflow in classrooms, set univent controls to “high”.

3. Inspect exhaust motors and belts periodically for proper function. Repair and replace as necessary.
4. Remove all blockages from univents and exhaust vents to ensure adequate airflow.
5. Consult a ventilation engineer concerning re-balancing of the ventilation systems. Ventilation industrial standards recommend that mechanical ventilation systems be balanced every five years (SMACNA, 1994).
6. Adopt scrupulous cleaning practices. For buildings in New England, periods of low relative humidity during the winter are often unavoidable. Therefore, scrupulous cleaning practices should be adopted to minimize common indoor air contaminants whose irritant effects can be enhanced when the relative humidity is low. Drinking water during the day can help ease some symptoms associated with a dry environment (throat and sinus irritations).
7. Report any roof leaks or other signs of water penetration to the school maintenance department for prompt remediation.
8. Replace any porous water-damaged building materials, once roof leaks are under control. Examine the area above and beneath these areas for microbial growth. Disinfect areas of water leaks with an appropriate antimicrobial. Clean areas of antimicrobial application when dry.
9. Move plants away from univents in classrooms. Avoid over-watering and examine drip pans periodically for mold growth. Disinfect with an appropriate antimicrobial where necessary.
10. Seal areas around sinks to prevent water-damage to the interior of cabinets and adjacent wallboard. Inspect adjacent areas for water-damage and mold/mildew growth,

repair/replace as necessary. Disinfect areas of microbial growth with an appropriate antimicrobial as needed.

11. Store cleaning products and chemicals properly and keep out of reach of students.
12. Store flammables in a cabinet that meets the standards for storage of flammable substances set by the National Fire Protection Association (NFPA, 1996).
13. Relocate or consider reducing the amount of materials stored in classrooms to allow for more thorough cleaning. Clean items regularly with a wet cloth or sponge to prevent excessive dust build-up.
14. Consider developing a written notification system for building occupants to report indoor air quality issues/problems. Have these concerns relayed to the maintenance department/ building management in a manner to allow for a timely remediation of the problem.
15. Ensure photocopiers, computers and other heat generating office equipment are not located close proximity to thermostats.
16. Clean animal cages and change lining material on a regular basis.
17. Consider discontinuing the use of tennis balls on chairs to prevent latex dust generation.
18. Consider adopting the US EPA document, "Tools for Schools" as a method for maintaining a good indoor air quality environment. This document can be downloaded from the Internet at http://www.epa.gov/iaq/schools/index.html.
19. Refer to resource manuals and other related indoor air quality documents for further building-wide evaluations and advice on maintaining public buildings. These materials are located on the MDPH's website at http://www.state.ma.us/dph/beha/iaq/iaqhome.htm.

The following **long-term measures** should be considered:

1. Examine the feasibility of replacing UFAIs with vertical louvers with properly pitched grilles.
2. Repair/replace seams between pilasters and concrete support beams in the exterior wall blocks. Consider installing flashing in these seams.
3. Repair/replace missing or damaged window caulking and gaskets building-wide to prevent water penetration through window frames. Examine all water-damaged materials for microbial growth and structural integrity. Repair water damaged ceilings, walls and wall-plaster as necessary.
4. Consider installing ceiling-mounted univents or alternate air handling equipment in ground floor classrooms and the cafeteria to prevent flooding during heavy rain.

References

ASHRAE. 1989. *Ventilation for Acceptable Indoor Air Quality.* American Society of Heating, Refrigeration and Air Conditioning Engineers. ANSI/ASHRAE 62-1989

Berry, M.A. 1994. *Protecting the Built Environment: Cleaning for Health,* Michael A. Berry, Chapel Hill, NC.

BOCA. 1993. The BOCA National Mechanical Code-1993. 8th ed. Building Officials & Code Administrators International, Inc., Country Club Hills, IL.

Camp Dresser and McKee. 1997. *Phase I Initial Site Investigation Report, Tobin Elementary School, Cambridge, MA*, *DEP RTN #E3-1658*. Cambridge, MA: July 2, 1997.

Environmental Health & Engineering, Inc. 1991. *An Assessment of Indoor Air Quality and Ventilation at the Tobin Elementary School, Project No. 90.080*. Newton, MA: dated April 12, 1991.

GEI Consultants, Inc. 1992. Letter to James Conry from Margret Hanley regarding Results of Soil Gas Monitoring at Tobin School, Cambridge, MA, Project 91283. Winchester, MA: dated March 5, 1992.

Haley & Aldrich, Inc. 1986. Letter to Cambridge School System regarding Air Quality Monitoring at the Tobin School, File No. 615300. Cambridge, MA: dated October 31, 1986.

IICR. 2000. IICR S001 Reference Guideline for Professional On-Location Cleaning of Textile Floor Covering Materials Institute of Inspection, Cleaning and Restoration Certification. Institute of Inspection Cleaning and Restoration, Vancouver, WA.

MA Department of Environmental Protection. 1991. *Letter to James Conry regarding GEI Soil Testing Report for Tobin School, DEP Case No. 3-1658*. Woburn, MA: dated December 17, 1991.

Mass. Act. 2000. *An Act Protecting Children and families from Harmful Pesticides*. 2000 Mass Acts c. 85 sec. 6E.

McGrath, ML. 1991a. *Memorandum to Robert Healy, City Manager Regarding Emergency Contracting for Tobin School Air Quality Work*. Cambridge, MA: dated August 22, 1991.

McGrath, ML. 1991b. *Letter to Cambridge School Committee regarding Tobin School Air Quality – Status Report*. Cambridge, MA: dated October 1, 1991.

McGrath, ML. 1991c. *Letter to Tobin School Parents and Staff regarding Various Testing Results*. Cambridge, MA: dated November 22, 1991.

NFPA. 1996. Flammable and Combustible Liquids Code. 1996 ed. National Fire Prevention Association, Quincy, MA. NFPA 30.

NIOSH. 1997. NIOSH Alert Preventing Allergic Reactions to Natural Rubber latex in the Workplace. National Institute for Occupational Safety and Health, Atlanta, GA.

NIOSH. 1998. *Latex Allergy: A Prevention Guide*. National Institute for Occupational Safety and Health, Atlanta, GA.

OccuHealth, Inc. 1991. *Final Report on the Air Sampling for Methane and Volatile Organic Compounds at the Tobin School, Cambridge, MA*. Mansfield, MA: December 1991.

OccuHealth, Inc. 1992a. *Final Report on the Methane and Pressure Tests at the Tobin School, Cambridge, MA.* Mansfield, MA: November 1992.

OccuHealth, Inc. 1992b. *Preliminary Report on the Ventilation System Study, Tobin School, Cambridge, MA.* Mansfield, MA: January 1992.

OccuHealth, Inc. 1999. *Memorandum to James Rita regarding Indoor Air Monitoring Survey Findings at Tobin School, Cambridge, MA, OHI No, 9095-07.* Mansfield, MA: dated April 20, 1999.

OccuHealth, Inc. 2000a. *Airborne Fungi Testing, Tobin Elementary School, Cambridge, MA.* Mansfield, MA: November 28, 2000.

OccuHealth, Inc. 2000b. *Indoor Air Quality Testing at Tobin School, Cambridge, MA, conducted February 16, 2000*. Mansfield, MA: March 27, 2000.

OccuHealth, Inc. 2000c. *Indoor Air Quality Testing at Tobin School, Cambridge, MA, November 2000*. Mansfield, MA: December 29, 2000.

OccuHealth, Inc. 1992a. *Final Report on the Methane and Pressure Tests at the Tobin School, Cambridge, MA.* Mansfield, MA: November 5, 1992.

OSHA. 1997. Limits for Air Contaminants. Occupational Safety and Health Administration. Code of Federal Regulations. 29 C.F.R 1910.1000 Table Z-1-A.

Sanford. 1999. Material Safety Data Sheet (MSDS No: 198-17). Expo® Dry Erase Markers Bullet, Chisel, and Ultra Fine Tip. Sanford Corporation. Bellwood, IL.

SBAA. 2001. Latex In the Home And Community Updated Spring 2001. Spina Bifida Association of America, Washington, DC. Http://www.sbaa.org/html/sbaa_mlatex.html

SBBRS. 1997. Mechanical Ventilation. State Board of Building Regulations and Standards. Code of Massachusetts Regulations. 780 CMR 1209.0

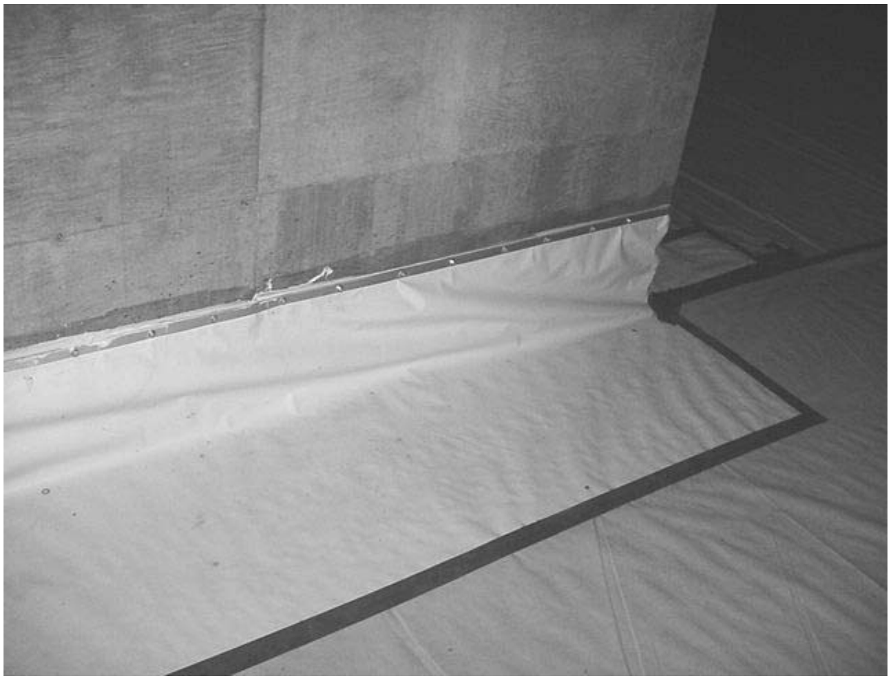
Schmidt Etkin, D. 1992. Office Furnishings/Equipment & IAQ Health Impacts, Prevention & Mitigation. Cutter Information Corporation, Indoor Air Quality Update, Arlington, MA.

Simpson Gumpertz and Heger. 1991. Draft report regarding Crawlspace Investigation, Tobin Elementary School, Cambridge, MA. Arlington, MA: August 30, 1991.

SMACNA. 1994. HVAC Systems Commissioning Manual. 1st ed. Sheet Metal and Air Conditioning Contractors' National Association, Inc., Chantilly, VA.

US EPA. 1992. Indoor Biological Pollutants. US Environmental Protection Agency, Environmental Criteria and Assessment Office, Office of Health and Environmental Assessment, Research Triangle Park, NC. ECAO-R-0315. January 1992.

Picture 1

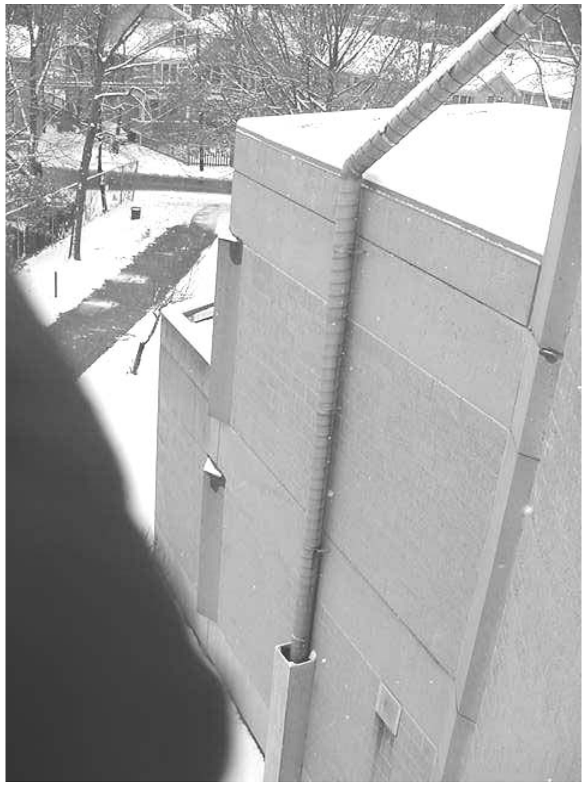


Crawlspace Impermeable Membrane Barrier

Picture 2

Component Crawlspace Sub-Slab Ventilation System

Picture 3



Duct to Roof That Is a Component Crawlspace Sub-Slab Ventilation System

Picture 4

An Exhaust Stack for the Crawlspace Sub-Slab Ventilation System

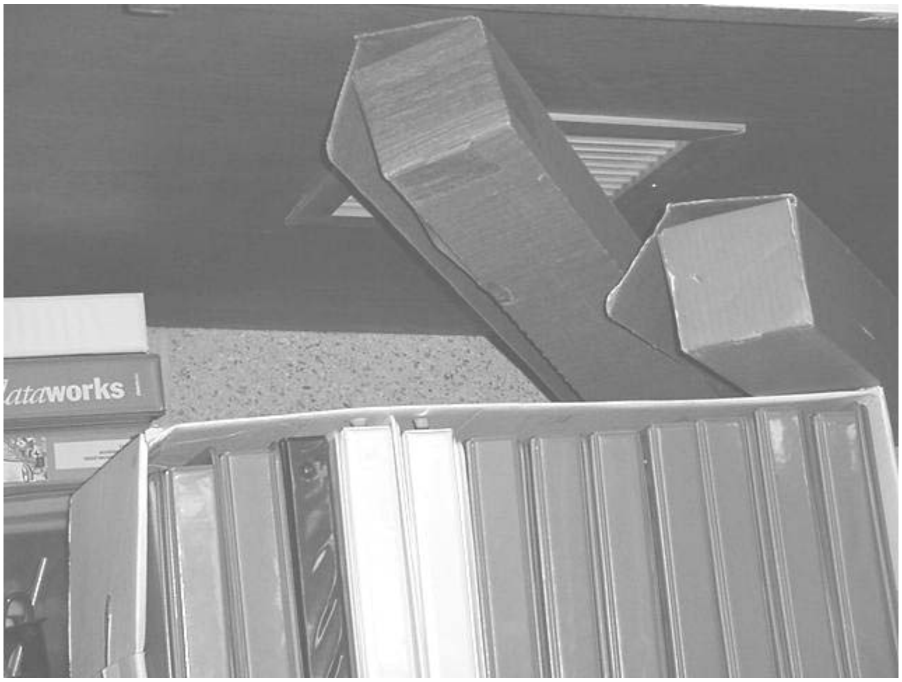
Picture 5

Plants and Other Items on And In Front Of Classroom Univent

Picture 6

Undercut Classroom Coat Closets Containing Exhaust Vents

Picture 7

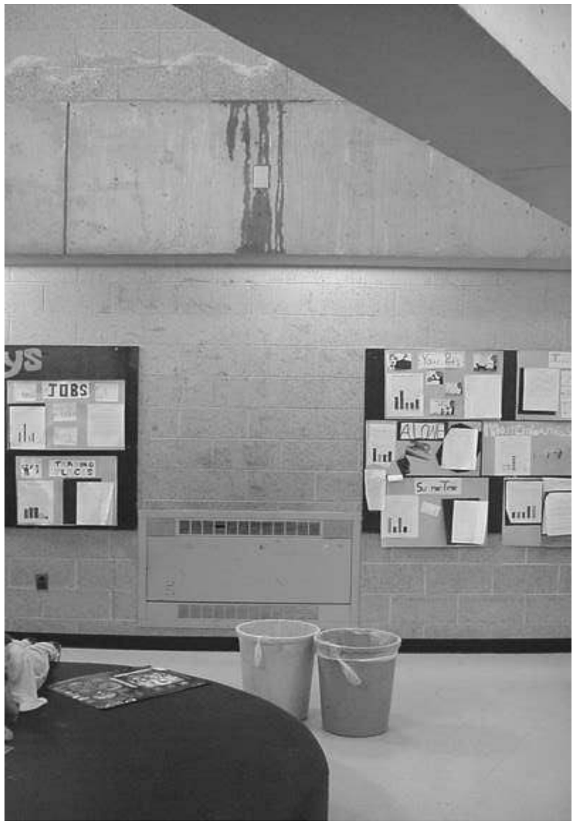


Classroom Exhaust Vent in Coat Closet Obstructed by Stored Items

Picture 8

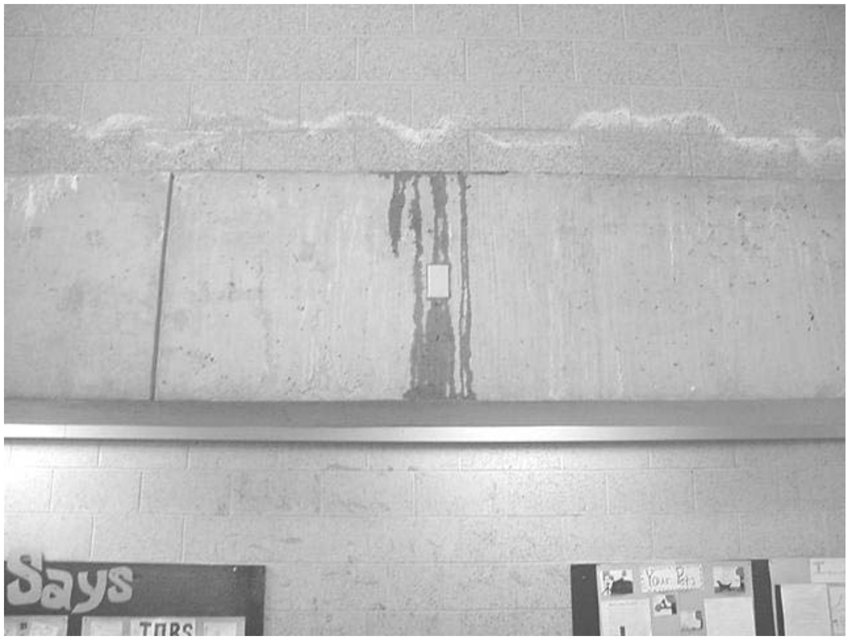
Water-Damage and Stained Building Materials

Picture 9



Buckets Were Stationed Throughout the Hallway to Catch Dripping Rainwater

Picture 10

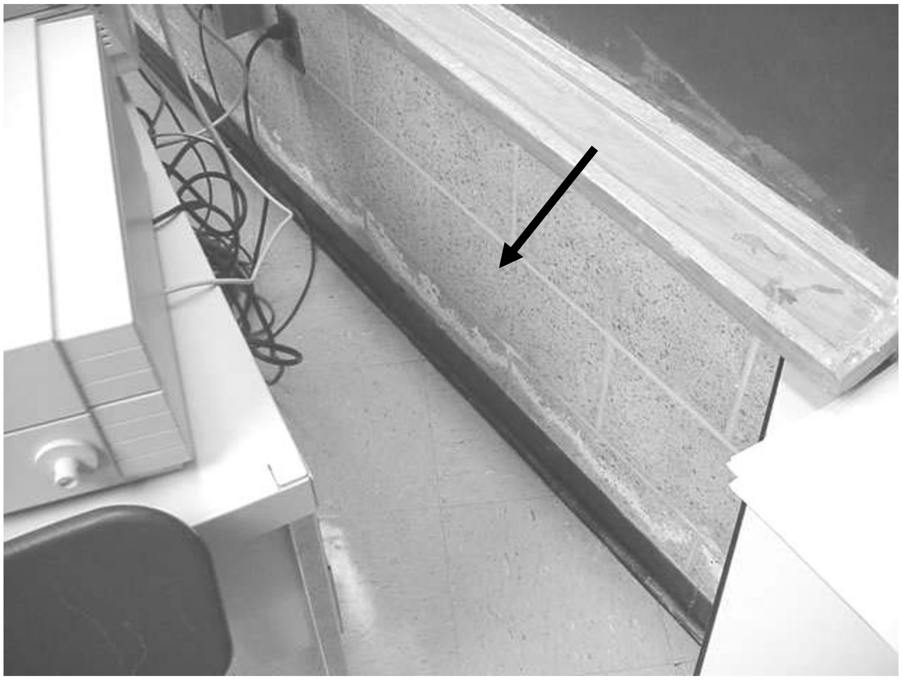


Efflorescence on Hallway Wall

Picture 11

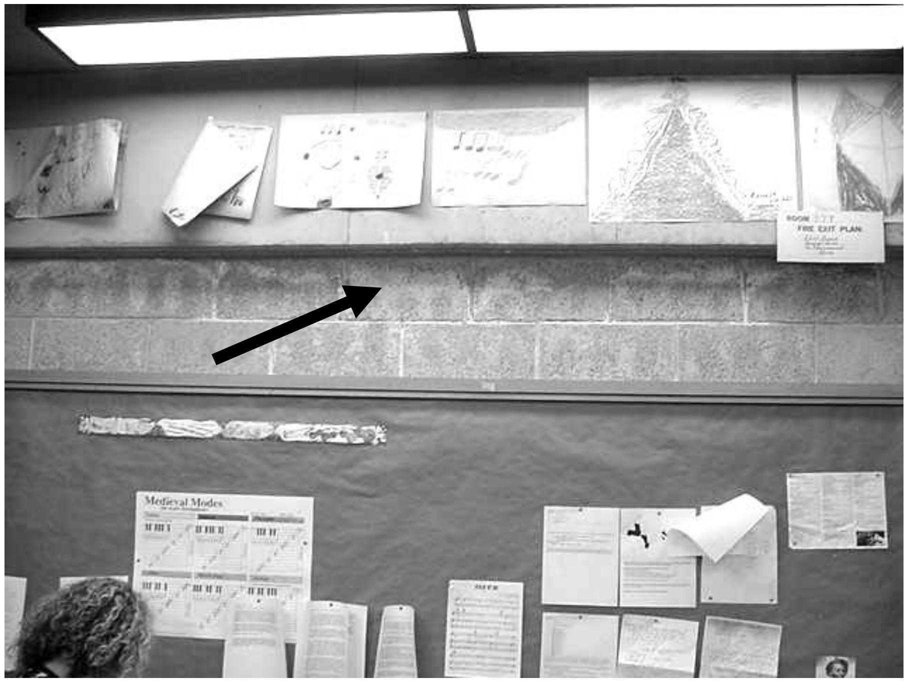
Efflorescence on Music Room Walls around Cement Beams

Picture 12



Efflorescence on Wall of Classroom

Picture 13

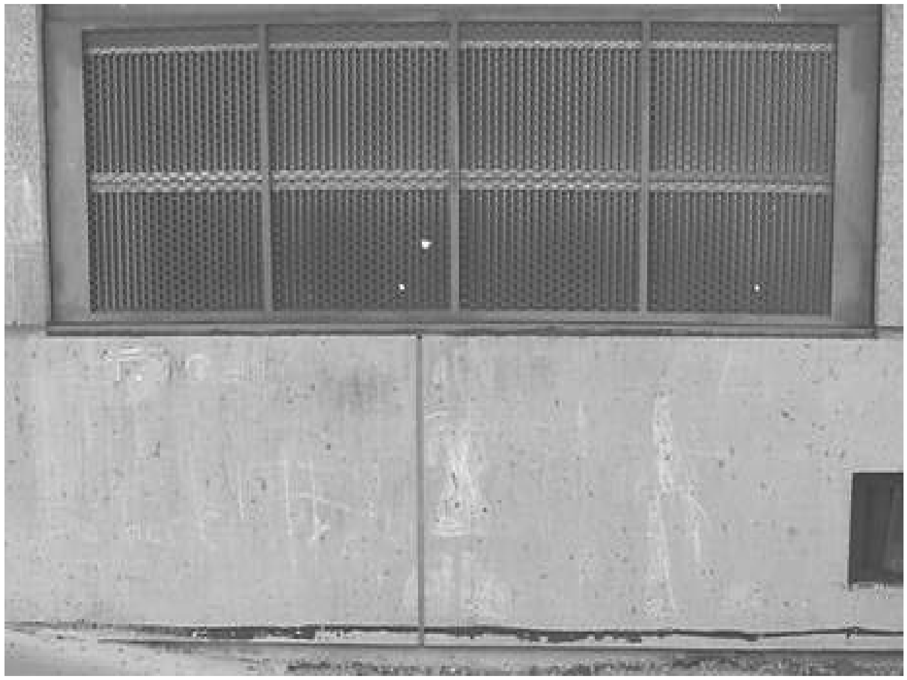


Efflorescence on Wall of Classroom

Picture 14

An Example of a Typical Univent Fresh Air Intake with Louver Vents Installed Parallel to the Ground (Murkland Elementary School, Lowell, MA)

Picture 15

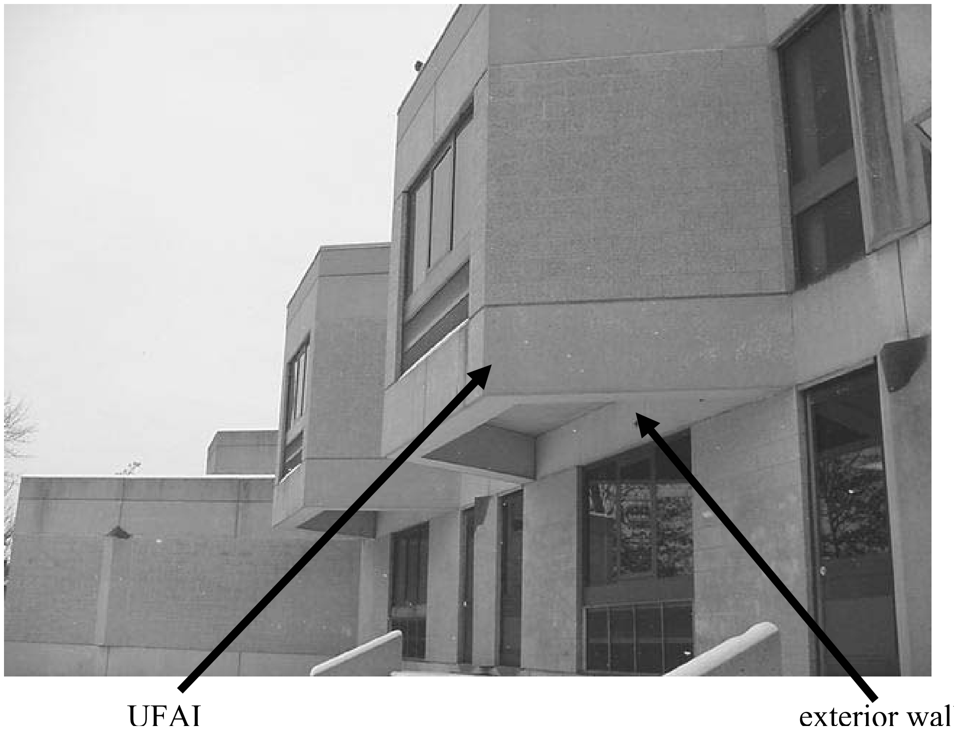


Exterior Univent Fresh Intake Grille Installed With Louvers Perpendicular to the Ground

Picture 16

Snow on Air Intake Louvers Inside Gymnasium AHU

Picture 17



Upper Floor Classroom with Cantilever Overhang

Picture 18

Example of Cracking and Efflorescence in Cement beneath and Behind UFAI

Picture 19

Classroom UFAIs Installed Near Ground Level

Picture 20

Cafeteria UFAIs Installed Near Ground Level at Bottom of Slope

Picture 21

Lower Roofs That Are Joined To an Exterior Wall of the Building

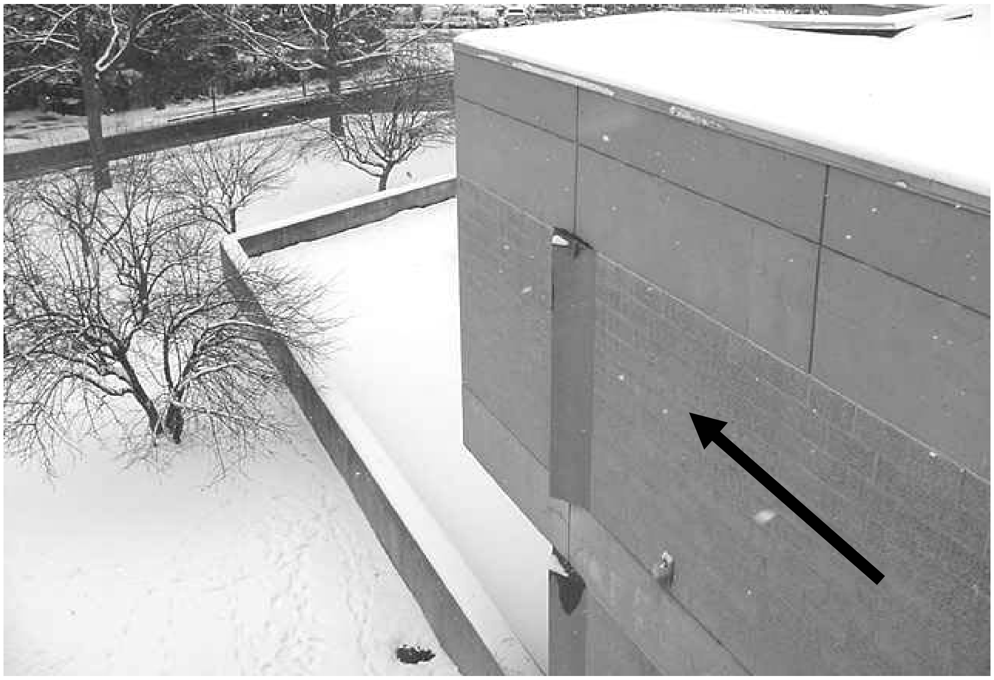
Picture 22

Lower Roof Drain Installed at Roof/Wall Junction

Picture 23

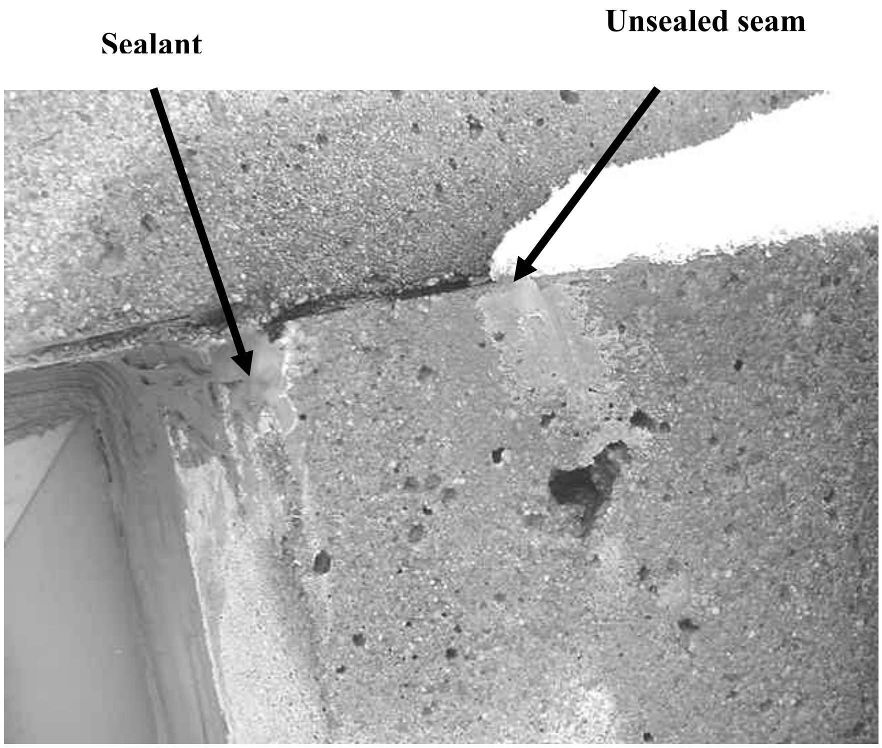
Water Spilling off Edge of Roof, Note Dryness of Surrounding Walls

Picture 24



A Pilaster Built Into the Exterior Wall, Note Moistened Top

Picture 25



Pilaster with Cement on Top, Note Unsealed Seam and Accumulated Snow On Pilaster Top

Picture 26

Window with Worn Gasket (Note Outdoor Light Penetrating Between Window And Frame)

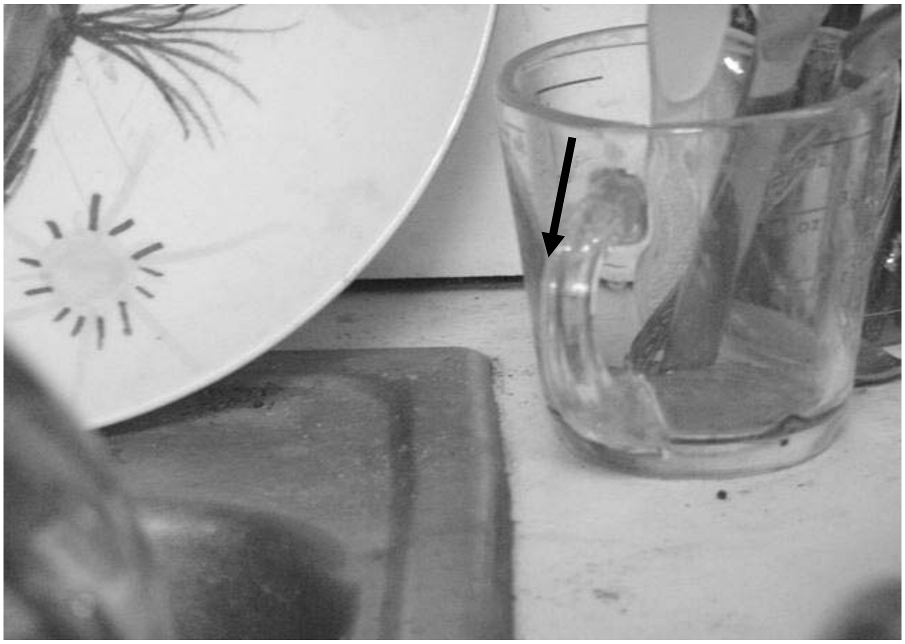
Picture 27

Missing/Damaged Window Caulking in Classroom

Picture 28

Cat Litter Spread at Base of Window Frame to Absorb Rainwater

Picture 29



Open Seam between Sink Countertop and Backsplash

Picture 30

Spray Cleaning Products in Unlocked Cabinet beneath Classroom Sink

Picture 31

Improperly Stored/Sealed Paints and Sealants on Classroom Countertop

Picture 32

Accumulated Items Stored in Classroom

TABLE 1

Indoor Air Test Results – Tobin School, Cambridge, Massachusetts — November 6, 2002

Remarks	Carbon Dioxide (*ppm)	Temp. (°F)	Relative Humidity (%)	Occupants in Room	Windows Openable	Ventilation		Remarks
						Intake	Exhaust	
Outside (Background)	263	51	86					
West Hallway (3rd Floor)								Water leak – buckets
Auditorium	510	69	42	12	Y	Y	Y	Curtain – odor
Library	657	72	40	15 +	Y	Y	Y	Plants, file cabinet blocking exhaust Door open
Teachers' Lounge	581	74	42	0	Y	Y	Y	Exhaust blocked with curtain Risograph, door open
Room 305	607	71	41	6	Y	Y	Y	Supply blocked by basket
Room 306	617	72	41	15	Y	Y	Y	Floor settling Hamster
Room 308	647	73	40	16	Y	Y	Y	Cat litter added to absorb water Water on floor

ppm = parts per million parts of air

DEM = dry erase board

UV = univent

Comfort Guidelines

Carbon Dioxide -	< 600 ppm = preferred 600 - 800 ppm = acceptable > 800 ppm = indicative of ventilation problems
Temperature -	70 - 78 °F
Relative Humidity -	40 - 60%

TABLE 1

Indoor Air Test Results – Tobin School, Cambridge, Massachusetts November 6, 2002

Remarks	Carbon Dioxide (*ppm)	Temp. (°F)	Relative Humidity (%)	Occupants in Room	Windows Openable	Ventilation		Remarks
						Intake	Exhaust	
Room 309	705	73	39	19	Y	Y	Y	Clutter
Room 310	620	74	38	16	Y	Y	Y	Clutter Water-damaged wall board
Room 311 Unoccupied Occupied	 466 552	 72 73	 42 39	 0 3	Y	Y	Y	Flowery plants
Room 312	644	71	42	3	Y	Y	Y	Clutter Door open
Room 313	618	71	41	0	Y	Y	Y	Clutter, WB Exhaust off, door open
Room 321	788	73	44	13	Y	Y	Y	17 computers, table rev. Door open
Room 322	683	72	46	20	Y	Y	Y	24 computers Door open
Room 336	510	70	44	16	Y	Y	Y	UV off; Door open; Passive door vent sealed; water through walls;

ppm = parts per million parts of air

DEM = dry erase board UV = univent

Comfort Guidelines

Carbon Dioxide -	< 600 ppm = preferred 600 - 800 ppm = acceptable > 800 ppm = indicative of ventilation problems
Temperature -	70 - 78 °F
Relative Humidity -	40 - 60%

TABLE 1

Indoor Air Test Results – Tobin School, Cambridge, Massachusetts November 6, 2002

Remarks	Carbon Dioxide (*ppm)	Temp. (°F)	Relative Humidity (%)	Occupants in Room	Windows Openable	Ventilation		Remarks
						Intake	Exhaust	
								efflorescence
Room 337	623	71	43	3	Y	Y	Y	Supply off; old WB
Room 338	342	70	41	0	Y	Y	Y	Chemical hood off
Room 339	361	72	39	0	Y	Y	Y	Upholstered furniture Efflorescence
Room 340	532	73	42	14	Y	Y	Y	Door open; Exhaust off Efflorescence
Room 341	484	72	41	1	Y	Y	Y	Water-damage – sink Widow gaskets; door open
Room 342	765	70	47	19	Y	Y	Y	Water-damage – sink Efflorescence
Room 343	981	68	51	17	Y	Y	Y	Water-damage – sink Efflorescence

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DEM = dry erase board UV = univent

Comfort Guidelines

Carbon Dioxide - < 600 ppm = preferred
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Temperature - 70 - 78 °F
Relative Humidity - 40 - 60%

TABLE 1

Indoor Air Test Results – Tobin School, Cambridge, Massachusetts **November 6, 2002**

Remarks	Carbon Dioxide (*ppm)	Temp. (°F)	Relative Humidity (%)	Occupants in Room	Windows Openable	Ventilation		Remarks
						Intake	Exhaust	
Room 344	679	72	41	0	Y	Y	Y	Water-damage – sink Efflorescence
Room 345	831	73	42	1	Y	Y	Y	Exhaust off
Room 346	628	73	40	4	Y	Y	Y	Door open Exhaust off
Room 347	544	73	40	3	Y	Y	Y	
Room 357								

ppm = parts per million parts of air

DEM = dry erase board

UV = univent

Comfort Guidelines

Carbon Dioxide -	< 600 ppm = preferred
	600 - 800 ppm = acceptable
	> 800 ppm = indicative of ventilation problems
Temperature -	70 - 78 °F
Relative Humidity -	40 - 60%

TABLE 2

Indoor Air Test Results – Tobin School, Cambridge, Massachusetts December 6, 2002

Remarks	Carbon Dioxide (*ppm)	Temp. (°F)	Relative Humidity (%)	Occupants in Room	Windows Openable	Ventilation		Remarks
						Intake	Exhaust	
Outside (Background)	406	40	26					Light breeze, light snow flurries
West Hallway (2nd Floor)	569	72	22	4	N	Y	Y	
Art Room	426	66	27	0	Y	Y	Y	
Cafeteria	471	64	29	75 +	Y	Y	Y	
Lounge 272	437	70	25	0	Y	Y	Y	Coke machine
Main Office	577	73	22	4	Y	Y	Y	Items on/in front UV; Photocopier below thermostat
Mechanical Room								2 AHUs
Room 128	464	66	21	0	Y	Y	Y	Hole in wall near thermostat, UV deactivated, items on UV
Room 129	461	68	22	0	Y	Y	Y	Unit exhaust vent off

ppm = parts per million parts of air

UV = univent

Comfort Guidelines

Carbon Dioxide -	< 600 ppm = preferred 600 - 800 ppm = acceptable > 800 ppm = indicative of ventilation problems
Temperature -	70 - 78 °F
Relative Humidity -	40 - 60%

TABLE 2

Indoor Air Test Results – Tobin School, Cambridge, Massachusetts December 6, 2002

Remarks	Carbon Dioxide (*ppm)	Temp. (°F)	Relative Humidity (%)	Occupants in Room	Windows Openable	Ventilation		Remarks
						Intake	Exhaust	
Room 129-B	448	67	25	2	Y	Y	N	Upholstery Pillows – food
Room 130	528	67	31	2	Y	Y	Y	
Room 204	473	71	20	1	Y	Y	Y	
Room 206	876	72	22	15	Y	Y	Y	Items on UV, plant in stand Water over UV, cleaning product under sink, spaces
Room 208	447	73	21	0	Y	Y	Y	Bag of dirt
Room 209	584	73	24	3	Y	N	N	Fan in wall Sink -
Room 209	457	71	22	1	Y	Y	Y	
Room 210	432	73	22	1	Y	Y	Y	

ppm = parts per million parts of air

UV = univent

Comfort Guidelines

Carbon Dioxide -	< 600 ppm = preferred 600 - 800 ppm = acceptable > 800 ppm = indicative of ventilation problems
Temperature -	70 - 78 °F
Relative Humidity -	40 - 60%

TABLE 2

Indoor Air Test Results – Tobin School, Cambridge, Massachusetts December 6, 2002

Remarks	Carbon Dioxide (*ppm)	Temp. (°F)	Relative Humidity (%)	Occupants in Room	Windows Openable	Ventilation		Remarks
						Intake	Exhaust	
Room 211	514	75	18	0	Y	Y	Y	Items on UV Door open
Room 212	501	76	19	1	Y	Y	Y	Cleaning product on sink Plants
Room 213	485	74	18	2	Y	Y	Y	Plants on UV, spaces on countertop Spray cleaning product on sink Tennis balls on chair
Room 215		72	21	11	Y	Y	Y	Door open, plants on UV Cleaning product – spray under sink
Room 216	646	72	20	3	Y	Y	Y	
Room 221	423	71	22	0	Y	Y	Y	Supply off
Room 223	402	72	22	1	Y	Y	Y	
Room 233	511	72	20	1	N	Y	Y	

ppm = parts per million parts of air

UV = univent

Comfort Guidelines

Carbon Dioxide -	< 600 ppm = preferred 600 - 800 ppm = acceptable > 800 ppm = indicative of ventilation problems
Temperature -	70 - 78 °F
Relative Humidity -	40 - 60%

TABLE 2

Indoor Air Test Results – Tobin School, Cambridge, Massachusetts **December 6, 2002**

Remarks	Carbon Dioxide (*ppm)	Temp. (°F)	Relative Humidity (%)	Occupants in Room	Windows Openable	Ventilation		Remarks
						Intake	Exhaust	
Room 235	531	73	20	0	N	Y	Y	
Room 235	470	71	23	0	N	Y	Y	
Room 239	430	78	18	1	Y	Y	Y	Window open Spaces on countertop
Room 270	510	72	20	1	Y	N	Y	Door open
Room 271	454	71	20	0	Y	Y	Y	Items on front UV Plants on UV
Room 274	798	73	23	9	Y	Y	Y	Plants over UV; Blockade around UV; obstruct return; Spray cleaning products on sink; breach between sink/counter
Room 281	841	72	21	13	Y	Y	Y	Items on UV, furniture around UV, Plants on UV, Spray cleaner on sink
Room 282	492	71	20	0	Y	Y	Y	Items on front of UV; Fruit flies by sink area; Birds nest

ppm = parts per million parts of air

UV = univent

Comfort Guidelines

Carbon Dioxide -	< 600 ppm = preferred
	600 - 800 ppm = acceptable
	> 800 ppm = indicative of ventilation problems
Temperature -	70 - 78 °F
Relative Humidity -	40 - 60%

TABLE 2

Indoor Air Test Results – Tobin School, Cambridge, Massachusetts December 6, 2002

Remarks	Carbon Dioxide (*ppm)	Temp. (°F)	Relative Humidity (%)	Occupants in Room	Windows Openable	Ventilation		Remarks
						Intake	Exhaust	
Room 284	884	72	22	16	Y	Y	Y	Spaces under exterior door – drafts; breach between sink and counter; cleaning products under sink
Room 286	868	73	24	14	Y	Y	Y	Art items drying on UV
Room 287	673	71	25	13	Y	Y	Y	Food stored; clutter; efflorescence
Room 288	648	71	23	16	Y	Y	Y	Water-damaged sink; white board; clutter
Room 289	705	71	25	17	Y	Y	Y	Water-damaged sink, tennis balls Upholstered furniture
Room 290	664	71	26	11	Y	Y	Y	Tennis balls; Water-damaged sink; supply blocked

ppm = parts per million parts of air

UV = univent

Comfort Guidelines

Carbon Dioxide -	< 600 ppm = preferred 600 - 800 ppm = acceptable > 800 ppm = indicative of ventilation problems
Temperature -	70 - 78 °F
Relative Humidity -	40 - 60%

Tobin School

Cambridge, MA

Indoor Air Results

December 2, 2003

Table 3

Location/ Room	Temp (°F)	Relative Humidity (%)	Carbon Dioxide (*ppm)	Carbon Monoxide (*ppm)	TVOCs (*ppm)	PM2.5 (µg/m3)	Occupants in Room	Windows Openable	Ventilation Supply	Ventilation Exhaust	Remarks
Background	27	69	349	0-1	ND	10					N/NW wind ~ 18 mph, overcast with light snow
Art	71	19	492	ND	0.5	25	0	Y	Y	Y	Blocked by plants, grass cutting outdoors
Gym	71	18	473	ND	ND	3	21	N	Y	Y	Damage to exhaust vents
Gym hallway											Water damage to wall plaster
Library (Room 333)	73	20	564	ND	ND	4	5	Y	Y	Y	DO, univent blocked by boxes/clutter, exhaust blocked by clutter/furniture, plants, laminator
Library Office	73	20	583	ND	ND	5	0	N	N	Y	AD, cleaners (furniture polish, disinfectant). Spray adhesive, plants, burning toast odor
Nurse's office (Room 272)	73	19	736	ND	ND	32	2	Y	Y	Y	DO

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AP = air purifier
CD = chalk dust

DEM = dry erase marker
DO = door open
PC = photocopier

PF = personal fan
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Tobin School
Cambridge, MA

Indoor Air Results
December 2, 2003

Table 3

Location/ Room	Temp (°F)	Relative Humidity (%)	Carbon Dioxide (*ppm)	Carbon Monoxide (*ppm)	TVOCs (*ppm)	PM2.5 (µg/m3)	Occupants in Room	Windows Openable	Ventilation		Remarks
									Supply	Exhaust	
Office – General use room	73	21	605	ND	ND	4	3	N	Y	Y	DO, CD
Office - Main	74	20	587	ND	ND	5	6	Y	Y	Y	DO, univent blocked with clutter
Preschool	70	20	700	ND	0.5	5	7	Y	Y		Univent blocked by furniture
Resources (Room 282)	70	19	488	ND	ND	4	1	Y	Y	Y	Univent blocked/occluded with dirt/debris and plants; exhaust blocked/occluded by dirt/debris, clutter, and furniture; CD, DEM, cleaners, plants, food use/storage, burning odor
Science supplies (Room 223)	71	20	400	ND	ND	9	2	Y	Y	Y	DO, supply occluded by dirt/debris; exhaust blocked by boxes; PC, dust, clutter, open utility holes

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Temperature -	70 - 78 °F
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Tobin School

Cambridge, MA

Table 3

Indoor Air Results

December 2, 2003

Location/ Room	Temp (°F)	Relative Humidity (%)	Carbon Dioxide (*ppm)	Carbon Monoxide (*ppm)	TVOCs (*ppm)	PM2.5 (µg/m3)	Occupants in Room	Windows Openable	Ventilation Supply	Ventilation Exhaust	Remarks
Teachers' Lounge	70	21	644	ND	ND	10	0	Y	Y	Y	Univent off, supply blocked by clutter, exhaust occluded with dirt/debris, CD
Room 127	67	19	626	ND	0.05	5	2	Y	Y		Univent off, TB
Room 128	69	20	698	ND	0.5	6	12	Y	Y	Y	Food use/storage
Room 204	72	15	584	ND	ND	5	6	Y	Y	Y	Univent blocked by clutter, dried corn husks, nests
Room 206	72	19	964	ND	ND	5	18	Y	Y	Y	Breach between sink/counter, plants, cleaners
Room 208	73	18	953	ND	ND	7	20	Y	Y	Y	Clutter, cleaners, breach between sink/counter
Room 209a	73	15	566	ND	ND	7	0	Y	Y	Y	TB

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Tobin School **Indoor Air Results**

Cambridge, MA **December 2, 2003**

Table 3

Location/ Room	Temp (°F)	Relative Humidity (%)	Carbon Dioxide (*ppm)	Carbon Monoxide (*ppm)	TVOCs (*ppm)	PM2.5 (µg/m3)	Occupants in Room	Windows Openable	Ventilation Supply	Ventilation Exhaust	Remarks
Room 209b	73	15	602	ND	ND	7	3	Y	Y	Y	DO, TB
Room 210	73	17	778	ND	ND	8	0	Y	Y	Y	DO, cleaners, plants, breach between sink/counter
Room 211	72	13	500	ND	ND	3	0	Y	Y	Y	Pet animal, breach between sink/counter
Room 212	73	18	942	ND	ND	7	17	Y	Y	Y	TB, plants, cleaners, breach between sink/counter
Room 213	72	17	701	ND	ND	7	5	Y	Y	Y	Univent blocked by plants, TB, cleaners
Room 215	73	19	985	ND	ND	14	16	Y	Y	Y	TB
Room 221	72	20	535	ND	ND	6	1	Y	Y	Y	DO, Univent off, but ceiling supply on; univent and ceiling supply occluded with dirt/debris; exhaust off and back drafting; exhaust vent occluded/blocked with

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Tobin School **Indoor Air Results**

Cambridge, MA **December 2, 2003**

Table 3

Location/ Room	Temp (°F)	Relative Humidity (%)	Carbon Dioxide (*ppm)	Carbon Monoxide (*ppm)	TVOCs (*ppm)	PM2.5 (µg/m3)	Occupants in Room	Windows Openable	Ventilation		Remarks
									Supply	Exhaust	
											dirt/debris, clutter, and furniture; CD, PF, clutter, plants
Room 239	74	15	570	ND	ND	4	6	Y	Y	Y	Univent blocked by furniture, spaces around window frame, breach between sink/counter
Room 279	73	21	888	ND	ND	4	12	Y	Y	Y	Univent blocked with dirt/debris, plants, and furniture; items hanging from ceiling tiles, CD, DEM, cleaners, plants, nests, food use/storage
Room 281	71	21	823	ND	ND	6	16	Y	Y	Y	Univent blocked with clutter; exhaust occluded/blocked with dirt/debris; breach between sink/counter, CD, DEM, aquarium/terrarium, plants, food use/storage
Room 283	71	20	726	ND	ND	4	11	Y	Y	Y	Univent blocked with clutter; exhaust blocked occluded by dirt/debris, clutter, and boxes; cleaners, breach between sink/counter, odor

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Tobin School

Cambridge, MA

Indoor Air Results

December 2, 2003

Table 3

Location/ Room	Temp (°F)	Relative Humidity (%)	Carbon Dioxide (*ppm)	Carbon Monoxide (*ppm)	TVOCs (*ppm)	PM2.5 (µg/m3)	Occupants in Room	Windows Openable	Ventilation Supply	Ventilation Exhaust	Remarks
Room 284	72	23	1022	ND	ND	5	18	Y	Y	Y	Univent blocked/occluded by dirt/debris, clutter, and furniture; exhaust blacked by clutter, furniture, and boxes; CD, DEM, AD, aquarium/terrarium, breach between sink/counter
Room 286	71	18	771	ND	ND	15	16	Y	Y	Y	DO, breach between sink/counter
Room 287	71	17	658	ND	ND	7	1	Y	Y	Y	12 occupants left ~35 minutes prior to room assessment, DO, univent blocked by clutter, breach between sink/counter
Room 288	71	18	1071	ND	ND	9	20	Y	Y	Y	Univent blocked by clutter and furniture. Breach between sink/counter
Room 289	68	19	984	ND	ND	9	15	Y	Y	Y	Univent blocked by clutter and furniture, TB, UF, breach between sink/counter
Room 290	72	19	876	ND	ND	8	12	Y	Y	Y	Loose rubber gasket around window, UF, breach between sink/counter

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Tobin School

Cambridge, MA

Table 3

Indoor Air Results

December 2, 2003

Location/ Room	Temp (°F)	Relative Humidity (%)	Carbon Dioxide (*ppm)	Carbon Monoxide (*ppm)	TVOCs (*ppm)	PM2.5 (µg/m3)	Occupants in Room	Windows Openable	Ventilation Supply	Ventilation Exhaust	Remarks
Room 305	73	21	768	ND	ND	3	21	Y	Y	Y	Univent occluded with dirt/debris, exhaust blocked by clutter, CD, DEM, clutter, cleaners, paints, breach between sink/counter
Room 306	73	16	655	ND	ND	5	3	Y	Y	Y	Univent occluded with dirt/debris, pet animal, breaches between sink/counter
Room 308	73	14	582	ND	ND	4	13	Y	Y	Y	DO, univent blocked by clutter, broken window – window leaking at bottom, AP
Room 309	73	18	743	ND	ND	8	1	Y	Y	Y	DO, cleaners, breach between sink/counter
Room 311	73	19	586	ND	ND	3	0	Y	Y	Y	Univent blocked/occluded by dirt/debris, plants, and clutter, exhaust off, exhaust blocked by dirt/debris and clutter, CD, DEM, cleaners, plants, breach between sink/counter, latex gloves on top of univent
Room 312	74	17	751	ND	ND	6	4	Y	Y	Y	DO, Exhaust backdrafting

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Tobin School | **Indoor Air Results**
Cambridge, MA | **December 2, 2003**

Table 3

Location/ Room	Temp (°F)	Relative Humidity (%)	Carbon Dioxide (*ppm)	Carbon Monoxide (*ppm)	TVOCs (*ppm)	PM2.5 (µg/m3)	Occupants in Room	Windows Openable	Ventilation		Remarks
									Supply	Exhaust	
Room 315	73	21	528	ND	ND	3	1	Y	Y	Y	2 DO, univent blocked by furniture and clutter, exhaust blocked by clutter, CD, PF, cleaners
Room 318	72	17	757	ND	ND	6	3	Y	Y	Y	PC
Room 321	72	19	657	ND	ND	7	3	Y	Y	Y	~20 occupants left 1 hour prior to room assessment, ~25 computers
Room 322	72	15	602	ND	ND	5	0	Y	Y	Y	PC, ~25 computers
Room 323	71	17	727	ND	ND	9	19	Y	Y	Y	DO, univent blocked by plant, aquarium/terrarium, exhaust in chemical closet
Room 325	68	18	679	ND	ND	6	1	Y	Y	Y	Univent blocked by clutter, breach between sink/counter, dust, clutter, cleaners, aquarium/terrarium, 2 broken window panes

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Tobin School **Indoor Air Results**

Cambridge, MA **Table 3** **December 2, 2003**

Location/ Room	Temp (°F)	Relative Humidity (%)	Carbon Dioxide (*ppm)	Carbon Monoxide (*ppm)	TVOCs (*ppm)	PM2.5 (µg/m3)	Occupants in Room	Windows Openable	Ventilation Supply	Ventilation Exhaust	Remarks
Room 327	70	23	1032	ND	ND	8	19	Y	Y	N	DO, room divided in half, uses a hood exhaust
Room 337	70	22	713	ND	ND	4	3	Y	Y	Y	Univent off, supply blocked by clutter, exhaust occluded with dirt/debris, CD, DEM, cleaners, plants, plug-in fresher, burning coffee odor
Room 339	69	17	631	ND	ND	10	3	Y	Y	Y	UF, spaces around window frame
Room 340	73	15	549	ND	ND	5	0	Y	Y	Y	DO, loose window caulking, window frame appeared to be duct taped
Room 341	73	16	843	ND	ND	6	25	Y	Y	Y	Loose/damaged window caulking
Room 342	74	16	611	ND	ND	4	1	Y	Y	Y	
Room 343	75	15	521	ND	ND	3	0	Y	Y	Y	
Room 344	72	20	528	ND	ND	3	16	Y	Y	Y	DO, univent and exhaust occluded by dirt/debris, CD, cleaners, students sitting in front of univent

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Tobin School

Cambridge, MA

Indoor Air Results

December 2, 2003

Table 3

Location/ Room	Temp (°F)	Relative Humidity (%)	Carbo n Dioxide (*ppm)	Carbon Monoxide (*ppm)	TVOCs (*ppm)	PM2.5 (µg/m3)	Occupants in Room	Windows Openable	Ventilation		Remarks
									Supply	Exhaust	
Room 345	72	21	650	ND	ND	4	6	Y	Y	Y	Spray paint and gloss glaze on shelf, univent and exhaust occluded with first/debris, plants on top of univent, breaches in window frame, DEM, cleaners, plants, food use/storage
Room 346	74	25	1597	ND	ND	8	23	Y	Y	Y	Univent and exhaust blocked by clutter, breaches in window frame, cologne odor, pain can under sink, CD, DEM, clutter, cleaners, food use/storage
Room 347	73	23	1439	ND	ND	4	27	Y	Y	Y	Univent blocked with dirt/debris and clutter, CD, DEM, dust, cleaners, general room clutter, food use/storage

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Appendix I

Summary of Historical Environmental Testing at the Tobin Elementary School, Cambridge, MA.

The Cambridge School Department provided BEHA staff with copies of reports, letters, and memorandum concerning a number of indoor air quality investigations at the TS that were produced between 1986 to 2000. These reports suggest that the TS has a long history of concerns relating to landfill materials underlying the school and other IAQ issues.

The Cambridge School Department has made numerous attempts to address air quality issues. Activities can be divided into two genral categories: actions to address concerns related to the landfill pollutants and actions addressing indoor air quality.

Actions To Address Concerns Related To The Landfill Pollutants

A number of consultants were hired to determine the extent of contamination in the ground beneath the TS as well as address indoor air quality complaints. In response to odor complaints and crawlspace concerns, Haley & Aldrich, Inc (H&A) were hired to monitoring for volatile organic compounds[1] (VOCs) and methane gas in 1986. Air monitoring was conducted in the three crawlspaces beneath the building. At the time of 1986 investigation, the crawlspace were used to store a variety of materials. The north crawl space was used as storage for furniture, machinery, solvents, and paints. Both solvents and paints may contain VOCs. Furniture was also stored in the west crawl space. Low concentrations of VOCs were measured in the north crawl space. Methane

[1] VOCs and methane gas can be produced from landfills through the decomposition of materials within a landfill. Another possible source of VOCs in landfills can be from disposal of chemicals.

levels in the north, west and east crawl spaces were 500 parts per million (ppm), 100 ppm and 1000 ppm respectively (H&A, 1986). H&A concluded that methane[2] levels were "not at concentrations that would pose health hazards and unsafe conditions" (H&A, 1986). To eliminate methane gas accumulation in crawlspaces to prevent a fire hazard, H&A recommended sealing separated and/or settled floor slab areas with a sealing compound.

According to Camp Dresser and McKee (CDM), one consultant, NUS Corporation (NUS), conducted an investigation in September 1985 to assess health risks associated with hazardous materials that were alleged to have been disposed on-site by local chemical and industrial manufacturers (CDM, 1997). NUS's Preliminary Assessment of the Tobin School report was prepared for the Region I U.S. Environmental Protection Agency (EPA) Superfund Branch (no copy of the original NUS report was not provided to BEHA staff for review). An review of the NUS report concluded that "No Further Remedial Action" would be necessary from the federal Superfund Program (CDM, 1997) concerning hazardous materials that were alledged to exist onsite.

Camp, Dresser & McKee (CDM) conducted a Phase I Limited Subsurface Investigation in 1997 "to determine whether a release of contaminants has occurred associated with the fill material beneath the Tobin Elementary School property…[and] evaluate the hazards associated with the fill material" (CDM, 1997). This investigation was conducted at the behest of the MA Department of Environmental Protection (DEP) after a request from the Cambridge School Department, pursuant to DEP regulation

[2] Methane gas is a highly flammable material that has limited physiological effects. Concentrations of methane in a confined space can be a serious fire hazard.

concerning hazardous waste (310 CMR 40.0000). CDM completed the following activities as part of this investigation:

1. Conducted a ground conductivity survey to map the location of the fill materials;
2. Sampled and analyzed groundwater from existing monitoring wells in the area; and
3. collected and analyzed soil gas samples from beneath the school and from the roof vent stacks (CDM, 1997).

CDM reported finding “no evidence of total petroleum hydrocarbons (TPH), VOCs, semi-VOCs or trace metal contamination of groundwater in direct contact with landfill materials”. CDM made the following conclusions.

- The potential for groundwater exposure to hazardous materials inside the building was unlikely.
- No fill material was found on ground surface areas, therefore the risk of exposure through direct contact was unlikely.
- The lack of fill decomposition halted methane generation.
- Any remaining VOCs and methane were actively being eliminated by the specially retrofitted crawl space venting systems; therefore, any potential for air exposure was also unlikely.

As a result of CDM assessment, the DEP classified the TS as a Tier II site, a site with lower potential risk.

Environmental Health & Engineering Inc. (EH&E), conducted an assessment from October 1990 through January 1991. The report released in April 1991 detailed monitoring results for selected pollutants (e.g. VOCs, respirable suspended particulate matter, pesticides, microbes, dust mites and carbon dioxide) and provided an assessment of the ventilation system. Overall, "the measured concentrations of the selected pollutants were found to be below accepted air quality guidelines." (EH&E, 1991).

While no significant levels of pollutants were detected, a number of ventilation problems were observed. EH&E recommended repair and sealing of breaks in the foundation to minimize the intrusion of soil gas into the crawl spaces; (EH&E, 1991).

Due to continued air quality and crawl space concerns, a third consultant, Simpson Gumpertz & Heger Inc (SGH), was hired in August 1991. SGH was retained to provide design recommendations and oversight to remedial projects. To address VOC concerns, materials stored in the crawl spaces were removed. At the recommendation of SGH, various consulting firms were contracted to provide the following services:

1. Installation of a temporary membrane barrier and sealant in crawl spaces;
2. Installation of a sub-slab ventilation system in crawl spaces and the floor of Room 129;
3. Monitoring for indoor methane and VOC levels;
4. Investigation of soil gases;
5. Installation and testing of HVAC upgrade system;
6. Design and installation of a subsurface gas extraction system; and
7. Design and installation of a permanent crawl space barrier (SGH, 1991; McGrath, 1991a; McGrath, 1991b).

The installations of the temporary impermeable membrane barrier and sub-slab ventilation system were completed in September 1991. One month following the installations, GEI Consultants, Inc. (GEI) conducted soil gas testing.[3] .

Testing for soil gas was conducted October 23, 1991. On November 21, 1991, GEI gave verbal notification to the Cambridge School Department that preliminary analysis of data indicated elevated soil gas levels of methane and VOCs (McGrath, 1991c). Under the direction of the Cambridge School Department, pursuant to Massachusetts General Law Chapter 21E (MGL c.21E) and the Massachusetts Contingency Plan (MCP) (310 CMR 40.000), GEI contacted the Massachusetts Department of Environmental Protection (DEP) to notify the agency of the "release or potential threat of release of hazardous materials" (McGrath, 1991c). In a letter issued December 17, 1991, the DEP concluded an "imminent hazard" *did not exist* in the school, as the crawl space ventilation system was operating as designed (DEP, 1991).

In a letter report issued March 5, 1992, GEI concluded: "the presence of VOCs and significant methane concentrations indicates that a release of hazardous materials has occurred on or adjacent to the TS…[however] the source of the VOCs and methane is unknown." GEI indicated that the east crawl space was of greatest concern as significant methane and VOC soil gas concentrations were detected. Because soil gas testing was conducted only after the sub-grade venting system was installed, the history, extent and distribution of the soil gas contamination could not be determined. GEI recommended continued operation of the sub-slab ventilation system to prevent methane and VOC entrainment to occupant areas (GEI, 1992).

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[3] Soil gas testing refers to the sampling of gases in subsurface areas below the temporary barrier system in the crawl space locations.

Another consultant, OccuHealth, Inc. (OHI), conducted air testing for methane and VOCs at the same time as the GEI sampling in 1991. Testing was conducted on October 23, 1991 and samples were collected from each of the sub-slab ventilation systems exhaust stacks, as well as in classrooms, crawl spaces, and outside. OHI found that VOC levels found in all areas of the TS were within expected ranges of indoor concentrations reported by the US EPA (OHI, 1991). Trace levels of methane were also detected. Prior to the installation of the barrier and sub-slab ventilation system, methane levels were "unacceptably high" (OHI, 1991). To maintain methane levels at lower readings, OHI recommended the following:

1. Installation of a supervised methane gas monitoring system in the three crawl spaces and the main hallway above the cafeteria; and
2. Bimonthly methane monitoring of:
    a. Air within the TS at selected sites including the three crawl spaces and classrooms located on each floor;
    b. Stack gases exiting the six sub-slab suction systems; and
    c. Ambient air around the TS (OHI, 1991).

In the months following, OHI conducted methane monitoring. The initial assessment found no methane at the test ports. Tests also indicated a good static pressure field under the concrete slab in nearly all of the ports. The major exception was Room 129, where no negative pressure was detected. This was attributed to a potential blockage or improper installation. An investigation was launched to determine the cause for lack of pressure in this area. Subsequent monitoring was conducted on a monthly basis. Follow-up reports indicate that methane levels were being effectively controlled by the crawl space ventilation system. OHI recommended continued operation of the crawl space ventilation system (OHI, 1992a).

Actions Addressing Indoor Air Quality

The 1991 report, EH&E made a number of recommendations to improve indoor quality in the TS. These recommendations included:

1. Remove all carpeting that has been damaged by water and disinfect underlying area with a bleach solution;
2. Implement and adhere to a scrupulous cleaning regimen when using humidifiers;
3. Examine and maintain unit ventilators (univents) for proper functioning, replacing malfunctioning parts as needed;
4. Familiarize occupants with the functions of the unit ventilator and encourage occupants to keep univents turned on;
5. Lower temperature settings and adjust diffusers to increase air movement and enhance comfort levels; and
6. Reduce noise generated by univents (EH&E, 1991).

Long-term recommendations included the modification or replacement of existing ventilation systems in response to increases to class size or changes to room usage (EH&E, 1991).

As indicated by the EH&E report, the condition and proper functioning of univent systems were also of concern. To address these concerns, OHI also conducted an assessment of the ventilation system at TS in 1991. Carbon dioxide (CO_2) measurements were taken in a number of classrooms throughout the building. While unoccupied, CO_2

readings were at 350 ppm in a majority of rooms. Occupied classrooms had CO_2 measurements ranging from 725 – 1075 ppm. The preliminary report, issued January 1992, recommended replacement of the existing univent system. OHI also recommended energy management measures as a means of conserving energy and improving control to the HVAC system. Recommended conservation measures include the conversion of the hot water heater from electric to natural gas and upgrading of the large HVAC units for the auditorium, gymnasium and general areas with new gas fired rooftop units (OHI, 1992b).

OHI conducted a number of indoor air quality assessments sunsequent to their initial visit in 1991. Testing was conducted by OHI in March 1999, February 2000, and November 2000. Assessmntes made by OHI are divided into two general categories: mold samplanf and TVOC sampling.

Mold Sampling

On March 3, 1999, OHI conducted indoor air monitoring for after water was found entering offices from a roof leak. OHI recommended affected areas be “fogged” with a microbial sanitizer containing ammonium compound (OHI, 1999) to remove possible mold contamination.

OHI returned in October 2000 to conduct further fungi monitoring. OHI concluded that “indoor concentrations of viable airborne fungi were well within accepted levels” (OHI, 2000a).

Continued complaints of indoor air quality prompted additional test requests. OHI was requested to assess indoor air quality in February 2000 and again in November

2000. Air samples were collected for airborne viable fungi levels, as well as for the characterization of airborne dust. The February 2000 concluded that airborne fungi concentrations were “well within accepted levels”, and all fungal types identified were commonly found in building environments. Additionally, dust types found in the building were common forms typically found in schools. Sources of dust included building occupants and building materials, as well as outdoors. (OHI, 2000b)

Similar results were found during the November 2000 reassessment. Indoor fungi levels were within accepted levels. As with previous results, fungi and dust identified in the building are common to building environments. Levels of skin cell fragments, cellulosic fibers, and opaque particles were elevated in the school gymnasium. OHI concluded that the intense activity level and increased flow of outdoor air contributed to elevated particle measurements. (OHI, 2000c)

TVOC Sampling

OHI also conducted TVOC sampling in February 2000 and November 2000. Air samples were collected for the determination of total indoor VOC (TVOC) concentrations. The February 2000 assessment concluded that a majority of areas sampled had TVOC levels that were “very close to normal.” Slightly elevated TVOC levels measured in some areas could be attributed to recent painting activities at the school (OHI, 2000b)

Similar results were found during the November 2000 reassessment. According to the November 2000 OHI report, concerns were raised regarding the level and type of TVOCs found in the gymnasium crawl space. These TVOC levels, as well as other measurements made through out the building were “statistically equivalent” to outdoor TVOC measurements. Test results confirm that the sub-slab ventilation system is operating as designed (OHI, 2000c)

Renovations

Univents was replaced in the building in July 2002. Installation of the remainder of the new HVAC system and related components were completed by September 1992. A number of damaged and malfunctioning louvers were subsequently replaced.

References

Camp Dresser and McKee. 1997. *Phase I Initial Site Investigation Report, Tobin Elementary School, Cambridge, MA*, *DEP RTN #E3-1658*. Cambridge, MA: July 2, 1997.

Environmental Health & Engineering, Inc. 1991. *An Assessment of Indoor Air Quality and Ventilation at the Tobin Elementary School, Project No. 90.080*. Newton, MA: dated April 12, 1991.

GEI Consultants, Inc. 1992. Letter to James Conry from Margret Hanley regarding Results of Soil Gas Monitoring at Tobin School, Cambridge, MA, Project 91283. Winchester, MA: dated March 5, 1992.

Haley & Aldrich, Inc. 1986. Letter to Cambridge School System regarding Air Quality Monitoring at the Tobin School, File No. 615300. Cambridge, MA: dated October 31, 1986.

MA Department of Environmental Protection. 1991. *Letter to James Conry regarding GEI Soil Testing Report for Tobin School, DEP Case No. 3-1658*. Woburn, MA: dated December 17, 1991.

McGrath, ML. 1991a. *Memorandum to Robert Healy, City Manager Regarding Emergency Contracting for Tobin School Air Quality Work*. Cambridge, MA: dated August 22, 1991.

McGrath, ML. 1991b. *Letter to Cambridge School Committee regarding Tobin School Air Quality – Status Report*. Cambridge, MA: dated October 1, 1991.

McGrath, ML. 1991c. *Letter to Tobin School Parents and Staff regarding Various Testing Results*. Cambridge, MA: dated November 22, 1991.

OccuHealth, Inc. 1991. *Final Report on the Air Sampling for Methane and Volatile Organic Compounds at the Tobin School, Cambridge, MA*. Mansfield, MA: December 1991.

OccuHealth, Inc. 1992. *Preliminary Report on the Ventilation System Study, Tobin School, Cambridge, MA.* Mansfield, MA: January 1992.

OccuHealth, Inc. 1999. *Memorandum to James Rita regarding Indoor Air Monitoring Survey Findings at Tobin School, Cambridge, MA, OHI No, 9095-07.* Mansfield, MA: dated April 20, 1999.

OccuHealth, Inc. 2000a. *Airbrone Fungi Testing, Tobin Elementary School, Cambrdige, MA.* Mansfield, MA: November 28, 2000.

OccuHealth, Inc. 2000b. *Indoor Air Quality Testing at Tobin School, Cambridge, MA, conducted February 16, 2000*. Mansfield, MA: March 27, 2000.

OccuHealth, Inc. 2000c. *Indoor Air Quality Testing at Tobin School, Cambridge, MA, November 2000*. Mansfield, MA: December 29, 2000.

OccuHealth, Inc. 1992a. *Final Report on the Methane and Pressure Tests at the Tobin School, Cambridge, MA.* Mansfield, MA: November 5, 1992.